Field Trials and Evaluations of Radio Data System Traffic Message Channel

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The Radio Data System Traffic Message Channel (RDS-TMC) will be introduced in Europe in the mid-1990s. RDS provides for the transmission of a silent data channel on existing VHF-FM radio stations. TMC is one of the remaining RDS features still to be finalized. It will enable detailed, up-to-date traffic information to be provided to motorists in the language of their choice, thus ensuring a truly international service. As part of the European DRIVE program, the RDS-ALERT project has carried out field trials of RDS-TMC. Testing was undertaken prior to and during the RDS-ALERT project, and implications for the TMC service throughout Europe were considered. TMC offers an exciting prospect of a practical application of information technology suitable for the 1990s and into the next millennium. Further TMC developments will provide interfaces linking it to other intelligent vehicle-highway system technologies currently under development in the United States, Europe, and Japan.

Traffic congestion is one of the most serious problems affecting transportation in the United States today. The volume of traffic is increasing at an alarming rate and will continue to rise into the next century. These problems are, of course, not unique to the United States. Growth in international traffic is increasing congestion throughout Europe as the border controls between European Community member states are reduced.

A standardized system for providing detailed, up-to-date traffic information to motorists is paramount in an integrated approach to solving these congestion problems. Provision of this information in Europe must allow for the different languages spoken in the member states. The ability to present detailed information in the driver's preferred language would greatly enhance the effectiveness of a traffic information system.

The Radio Data System Traffic Message Channel (RDS-TMC) will provide such a traffic information service to European motorists before the end of the century. The RDS facility, defined by a European Broadcasting Union (EBU) specification (*1*), provides for the transmission of a silent data channel on existing VHF-FM radio stations. Its primary purposes are to identify radio broadcasters and to allow self-tuning receivers to automatically select the strongest signal carrying a particular program. One of the most popular RDS facilities is the program service name. This facility gives the listener a display of up to eight characters showing the name of the program being received, such as "BBC R4" for Radio 4 in the United Kingdom or, potentially, "WCXR" for the Washington classic rock station.

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Many RDS features have already been defined and implemented in most parts of Europe. One additional feature of RDS not yet finalized is the Traffic Message Channel (TMC) for digitally encoding traffic information messages. Group Type 8A, one of 32 possible RDS data groups, has been reserved for the TMC service. It will provide continuous information to motorists through a speech synthesizer or text display in the vehicle. TMC will improve traffic data dissemination into the vehicle by several orders of magnitude over conventional spoken warnings on the radio. By linking with intelligent vehicle-highway system (IVHS) technologies, TMC will interface with on-board computers, creating an additional tool for direction and control of traffic movements.

BACKGROUND

The concept of using a subcarrier to convey additional information on a VHF-FM broadcast dates back many years. By the mid-1960s, many FM stations in the United States used subcarriers to convey a subsidiary audio program signal. This "storecasting" was used to play background music in restaurants and shops (*2*). These subcarrier systems were subject to a Federal Communications Commission regulation known as Subsidiary Communications Authorization. These systems were not suitable for use in Europe because of the level of crosstalk from the subcarrier into the main audio program.

The Autofahrer Rundfunk Information (ARI) system was developed in West Germany in the early 1970s. ARI is a relatively simple tone-signaling system which requires only a simple decoder. It indicates which programs carry traffic announcements as part of the audio, when a traffic announcement is currently being broadcast, and the geographical area to which the announcement applies.

By the mid-1970s several European organizations were working toward the development of an FM subcarrier system using data to modulate the subcarrier. In 1978, EBU began working toward a standard for a station and program identification system for FM broadcasts. This work resulted in the RDS specification in 1984 (*1*).

The basic structure of the RDS service is shown in Figure 1. The data rate for RDS is 1187.5 baud, divided into groups of 104 bits. Each group is made up of four blocks of 26 bits each, of which 10 bits are used as a checkword. An RDS group is the smallest package of data that can be defined within the system. RDS is broadcast using a 57-kHz subcarrier; when an ARI signal is broadcast on the same subcarrier, the two signals are broadcast 90 degrees out of phase.

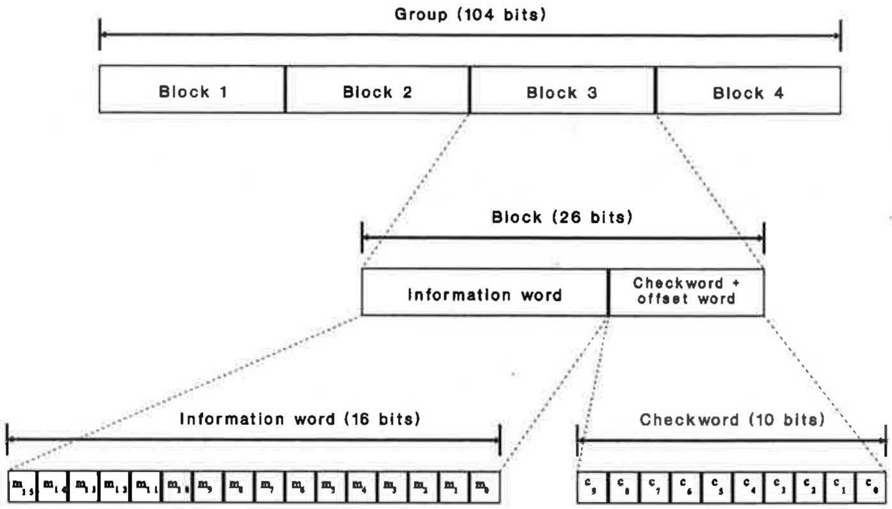

FIGURE 1 RDS group structure.

From the outset of the RDS development, it was foreseen that the system might be used as a channel to convey traffic messages. Three broad approaches were initially investigated for this service. They considered text-to-speech, phoneme transmission, and the use of a fixed repertoire of speech synthesizer messages. The third option, which uses a fixed repertoire of basic traffic messages stored as a dictionary in the receiver, was considered the most practical. The addition of supplementary dictionaries to include a store of place names would be possible by mass storage such as CD-ROM.

Since the development of the RDS specification, a number of proposals for the TMC feature have been made (*2*). The Dutch RVI project was one of the first. It began to investigate broadcasting traffic information via RDS in 1985. The project comprised the definition and implementation of a prototype system and the development of technical facilities to transmit traffic information using RDS. The RVI demonstration concluded that although RVI was not the optimal solution for a TMC service, it would be feasible to use speech synthesizers in vehicles to introduce a similar service throughout Europe.

The second main development in TMC came from Philips and Blaupunkt, who had been working separately on concepts for broadcasting traffic information via RDS. In 1986, the two manufacturers started to work together to develop a common proposal for the traffic message format. The proposed structure used a two-group RDS message to give incident cause, effect, location, and stop time, and to provide advice for the driver. This proposal was presented to the European Conference of Ministers of Transport (ECMT) in 1987.

From early 1987, TMC research in West Germany concentrated on reducing the redundancies in previous proposals. Blaupunkt and the West German Ministry of Transport (BAST) worked on a coding structure based on the messages used in the ARI system. The result was a one-group structure incorporating 90 percent of the ARI messages. This development increased the efficiency of earlier coding structures, but considered only those messages required in West Germany.

The CARMINAT project was launched in 1986 to investigate technological advances for improving car travel. The project focused on the implementation of an experimental area in France and was intended to evaluate and validate prototype systems. A protocol was developed to incorporate the traffic data collection, message generation, and message broadcast features of an RDS-TMC service. This protocol and others developed in CARMINAT are still evolving through demonstrations in the experimental area.

The Commission of the European Communities funded a study in 1987 and 1988 to examine how actual traffic messages would fit into a standard RDS-TMC format. A primary objective of the study was to bring together all of the national traffic messages developed to date and set up an agreed international set. An important aspect of the research was to canvass opinion in order to get a representative range of views.

The study, carried out by Castle Rock Consultants, led to a final report on the so-called CRC protocol for TMC in October 1988 (*3*). It defined an allocation of bits within RDS-TMC that offers the flexibility for covering a full range of situations while retaining the potential benefits of single-group messages for the majority of actual events. The first objective of the study was to resolve location coding issues. Second, it defined a comprehensive message coding structure to allow for basic message texts, advice, and message quantification such as queue length or incident duration. The third area of the study addressed the message management aspects of RDS-TMC.

The CRC protocol significantly increased the efficiency of the message coding developed in previous proposals. In conjunction with the revised location codes, it allowed the majority of messages to be broadcast using a single RDS group. The few multigroup messages containing additional, detailed information would be wholly compatible with the recommended one-group structure through the use of virtually identical fields in the first group.

RDS-ALERT

Leading on from the TMC coding studies, the European Community's DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) program addressed the development of

RDS-TMC. DRIVE I was a precompetitive, prenormative research and development program involving collaboration among over 1,000 transportation-related experts from 300 European organizations (*4*). Its conceptual goal was a fully integrated road transport environment (IRTE) in which intelligent vehicles are linked to an intelligent road network. This goal was to be reached by developments in information technology and telecommunications applied to road transport. Such technological developments are called Road Transport Informatics (RTI). DRIVE II will focus on field trials of the various technologies.

RDS-ALERT (Advice and Problem Location for European Road Traffic) was one of about 70 projects within DRIVE I. Its goal was establishing standards in RDS-TMC location coding, message content, and message management acceptable throughout Europe. An additional objective of the project was to ensure compatibility with other in-vehicle equipment. RDS-ALERT was undertaken by a consortium of manufacturers and broadcasters coordinated and led by Castle Rock Consultants. It was a 2-year project which started at the beginning of 1989.

Within RDS-ALERT, current proposals for single-group and multigroup messages were reviewed and evaluated in order to reach a starting consensus for experimental evaluation. A liaison group structure was established with representatives from EBU, ECMT, and the RDS-ALERT consortium to ensure the necessary integration with other RTI developments and among principal actors in RDS-TMC. Liaison was carried out through this group, with other programs, and through contacts with traffic authorities and broadcasters throughout Europe.

The RDS-ALERT project sought to establish internationally accepted standards in RDS-TMC coding, format, and operation for use as part of a road traffic information system. In finalizing a standard protocol for approval through this project, a comprehensive, flexible, and efficient approach has been sought. *Comprehensive* coding ensure that all required locations and messages can be coded. *Flexible* coding deals with current situations and allows for future changes in the highway networks. *Efficient* coding enables the limited capacity available for RDS-TMC to be used to its best advantage.

One of the major goals of the project was to provide for maximum flexibility of message coding in order to permit future, but unforeseen, TMC developments. Also, the project aims to develop consistent and agreed location coding strategies for countries wanting to implement RDS-TMC. In developing standards, RDS-ALERT defined optimal message management strategies and limits to permissible variations, taking into account the different situations of participating countries.

The RDS-ALERT project made substantial progress toward developing an international RDS-TMC standard. Field tests were carried out to evaluate the RDS broadcast and reception conditions in a number of countries. These field tests demonstrated the requirements for an efficient TMC coding structure. Building on the work of Castle Rock Consultants (*3*), a message set was derived to incorporate the messages required in each country interested in implementing an RDS-TMC service. This development is at the stage where messages can be input quickly and easily, resulting in a final RDS code for broadcast.

The final field trials in RDS-ALERT started early in 1990. These field trials, carried out on test routes in southeast England, used signal-quality results from a number of European countries to ensure that reception conditions were representative of those experienced on the European highway network. The results of the field trials were used to evaluate all aspects of the proposed TMC protocol. The draft protocol has been drawn up and circulated as part of the consensus-building process. This draft will require final modifications and refinements before full documentation of the protocol can be submitted to the relevant standard-setting bodies.

FIELD TRIALS

Testing of RDS reception has been carried out under many conditions in recent years. In 1987, Philips carried out extensive RDS field tests in West Germany (*2*). These tests evaluated the percentage of RDS blocks received with and without error-correction facilities, and looked at the loss of block reception prior to synchronization onto the RDS data stream. The test results showed that between 62 and 85 percent of blocks were received correctly. Using the error-correction facilities provided for in RDS, the number of correctly received blocks increased to between 73 and 89 percent.

In order to decode a single-group TMC message, all four blocks from the group must be correctly received. Because of the nature of the RDS data stream, bit errors are more likely to come in bursts than to be randomly distributed. Hence, if one block is received correctly, the probability of correctly receiving the subsequent block is increased. In Germany, BAST carried out studies of the RDS reception characteristics for single-group and multigroup TMC messages. The results of these studies showed that 80 percent of single-group messages could be correctly received under good reception conditions, decreasing to 18 percent for four-group messages.

The RDS and ARI signals are both broadcast on a 57-kHz subcarrier. When both systems are provided on the same station, interference is kept to a minimum by broadcasting the two signals 90 degrees out of phase. However, the two signals still interfere in mountainous areas where multipath effects are experienced. The level of interference for areas with both RDS and ARI broadcasts was tested by Bosch. These tests indicated that the ARI signal reduces the proportion of error-free blocks by up to 20 percent.

The RDS-ALERT project included four phases of field trials. The first phase was carried out in Germany using a professional Blaupunkt receiver and Schuemperlin decoder. The second phase of the testing took place in France with 10 transmitters equipped to broadcast RDS-TMC data. The third testing phase evaluated aspects of the TMC protocol based on the ISO seven-layer communications model. Finally, the fourth phase investigated RDS reception conditions in a number of countries over various terrains.

Phase One

Phase One tests used static data transmission techniques to broadcast a fixed TMC data set. These techniques allowed the same sequence of messages to be used under varying reception conditions. On test routes south of Hanover, Germany, results were recorded for

- Field strength,
- Signal quality,
- Group and block reception statistics, and
- Time for message reception.

The tests showed that even under relatively poor reception conditions it would be possible to receive TMC messages, although the delay might be as much as 5 minutes between initial broadcast and correct decoding in the vehicle (*5*). This finding highlighted the requirements for an efficient coding structure with as many messages as possible broadcast in a single RDS group.

Phase Two

Phase Two testing was carried out south of Paris, France. Traffic information was broadcast in real time using a draft TMC protocol. The tests examined

- Reception quality,
- Proportion of messages received incorrectly,
- Proportion of messages not received, and
- Data flow requirements for a fully implemented system.

These test results noted significant differences in reception conditions between urban and rural areas. The proportion of blocks correctly received was reduced by about 5 percent on entering an urban area (*6*). Overall, however, the results were favorable for successful operation of a TMC service.

Phase Three

Testing in *Phase Three* was based on test routes in southeast England. The field testing used wide-band recorders to record the full FM multiplex from two stations, both on-air in a test vehicle and directly from the 240-kW transmitter. Comparison of the on-air and direct recordings gave an error file that can be applied to any RDS data stream to simulate real conditions. The error file could therefore be used to evaluate draft TMC protocols under identical conditions. Preliminary results from these tests included the following findings:

Number of RDS Groups per Message	*Percentage of Messages Correctly Received*
0.5	86
1	84
2	77

These findings relate to the condition with no ARI signal on the same broadcast and with a deviation (width of the RDS signal, usually between 1.2 and 7.0 kHz) of 2 kHz. The tests indicated that no false messages were received, implying that all corrupted groups were rejected.

Phase Four

In *Phase Four*, Castle Rock Consultants conducted RDS signal-quality tests under the varying reception conditions experienced across Europe. Results were recorded with RDS decoders from Blaupunkt and Philips. The tests examined the range of field strengths and data error rates experienced in the areas where TMC will be implemented.

The testing using the Blaupunkt receiver covered Switzerland, Belgium, Germany, the United Kingdom, France, and the Netherlands. These tests were conducted in mountainous regions as well as flat land. Also, a number of RDS deviations were included in the tests, ranging from 1.2 kHz in Germany to 7 kHz in parts of France. The deviation refers to the width of the RDS signal on either side of the 57-kHz subcarrier. The tests in Germany covered radio stations using the ARI system as well as RDS.

The results from the Blaupunkt decoder comprised field strength and error rate readings along each of the routes for a particular program. About 8,000 readings were taken using this decoder, each providing an average over a 20-sec period. The results of the field strength tests are shown in Figure 2. The figure shows the percentage of readings in each country at particular field strengths. The service area for an FM transmitter is defined in the United Kingdom as the area in which the field strength is at least 54 dB relative to 1 uV/m (*7*). Figure 3 shows the bit error rate results for the same routes. The results shown in both figures are summarized in Table 1. The following paragraphs briefly analyze these results.

A number of important conclusions can be drawn from the field strength results. The mean field strengths show low values for France and the Netherlands and higher values for the other countries. Similarly, the variation in the field strengths for France and the Netherlands are larger. The main factors causing this variation are the transmitter power and spacing. In France, radio transmitters are not significantly lower in power than the rest of Europe, but their spacing is considerably greater.

The distributions differ significantly for the other four countries, although the mean field strengths are similar (59.3 to 60.0 dB). The United Kingdom field strengths, taken mostly from BBC stations, have the most consistent values with a standard deviation of 5.9 dB. Switzerland, Belgium, and Germany have standard deviations between 6.8 and 7.5 dB. Again, transmitter power and spacing are the main parameters affecting these results. The United Kingdom is covered by the BBC by over 30 main transmitters with powers up to 250 kW. In addition, nearly 100 smaller transmitters cover areas missed by the main network. The other countries considered do not have such comprehensive coverage.

The bit error rate results show some different trends. Generally, the bit error rates are expected to follow trends opposite those of the field strengths. However, in Switzerland and Germany, both the field strengths and the bit error rates are some of the highest. Also, although France and the Netherlands have relatively low field strengths, their bit error rates are around the average for all routes.

Terrain is one of the factors affecting the bit error rates in RDS reception. The Swiss and German results were obtained mostly from mountainous regions, typical of those countries.

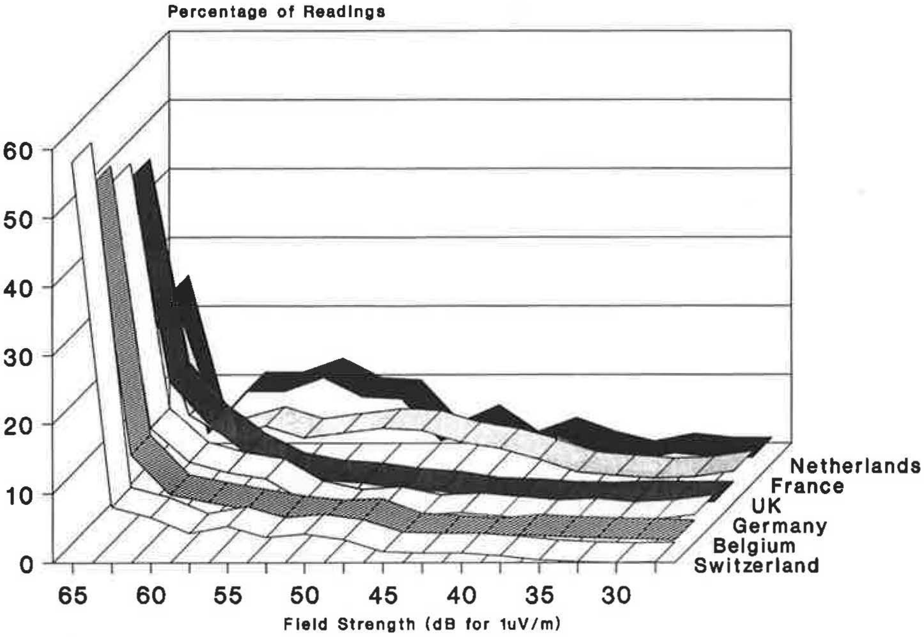

FIGURE 2 **RDS field strength results.**

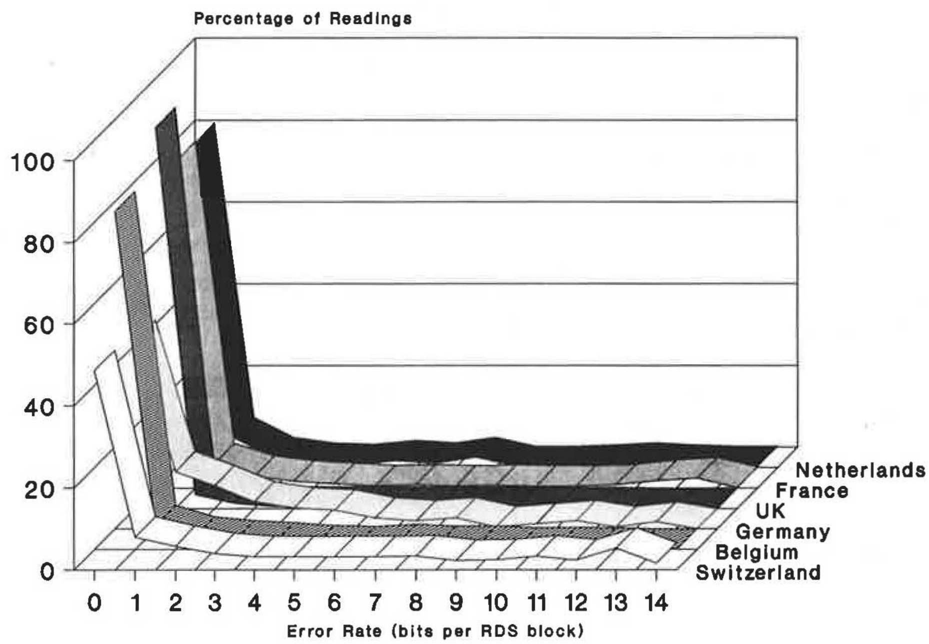

FIGURE 3 **RDS bit error rate results.**

This type of terrain results in multipath effects caused by signal reflections. Although multipath does not significantly affect the field strength, it can cause data errors. Conversely, the Netherlands and much of France consists of relatively flat land, resulting in lower bit error rates than normally expected for their mean field strengths.

The second main parameter affecting RDS bit error rates is the deviation used. In Germany the deviation is set at 1.2 kHz; in France many stations use up to 7 kHz. A high deviation means a wide RDS signal and therefore a lower probability of receiving data errors. The low deviation value is used in Germany to reduce the interference between the RDS and ARI signals. This combination of low deviation and ARI interference makes German reception conditions among the most testing in Europe.

The two receiver manufacturers in the RDS-ALERT consortium, Philips and Blaupunkt, adopt different transmitter switching strategies in their existing RDS receivers. The Blaupunkt receiver periodically tests some of the alternative frequencies in order to determine the strongest signal carrying a particular station. It switches to an alternative frequency only when the alternative has shown a consistently higher field

TABLE 1 SUMMARY OF RDS FIELD STRENGTH AND BIT ERROR RATE RESULTS

Country	Mean field strength (dB)	Standard deviation	Mean error rate (Bits/block)	Standard deviation	Number of readings
Switzerland	59.8	6.8	3.3	4.4	910
Belgium	59.3	7.5	0.6	1.8	1415
Germany	59.3	7.3	2.2	3.1	409
UK	60.0	5.9	0.2	1.0	2383
France	54.3	9.2	1.1	3.0	2829
Netherlands	54.8	8.3	0.9	2.5	355
All	57.7	7.7	1.0	2.6	8301

strength. The Philips receiver, on the other hand, tends to switch to an alternative frequency if the alternative has shown an instantaneously higher field strength.

Although both of these strategies have advantages for audio reception, neither of them is the optimal solution for TMC frequency switching. The Blaupunkt strategy would result in TMC messages transmitted from behind the vehicle. These messages would therefore relate to an area already passed through by the vehicle. The Philips strategy would overcome this problem to a degree by switching more readily. It would, however, be less efficient in that each frequency switch results in data losses before continuity can be gained.

Figure 4 shows results of tests using the Philips receiver to monitor four transmitters broadcasting the same BBC program in north England. Figure 5 shows the route followed during the test. The results highlight some of the disadvantages of each switching strategies. The Blaupunkt strategy would keep the receiver tuned to the Keighley transmitter until around 25 miles. It would then tune to Holme Moss and remain on that until the end of the route. The Philips strategy would tune to Holme Moss at 18 miles, but would also select Wharfedale for miles 49 and 50. The ideal strategy, however, would tune to Holme Moss at 18 miles, but would ignore the brief field strength peak from the Wharfedale transmitter because this would cause two data continuity losses within a short time.

This brief analysis highlights some of the differences in RDS reception across Europe and in current RDS receiver capabilities. TMC will need to operate successfully under all of these conditions. The results indicate the variations within

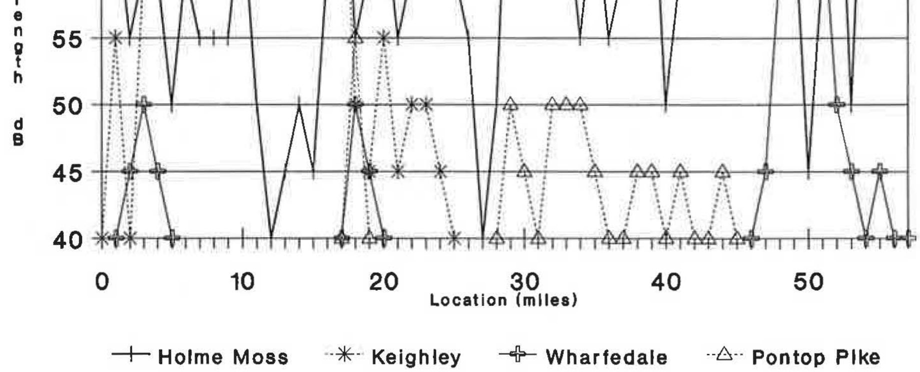

FIGURE 4 RDS test results.

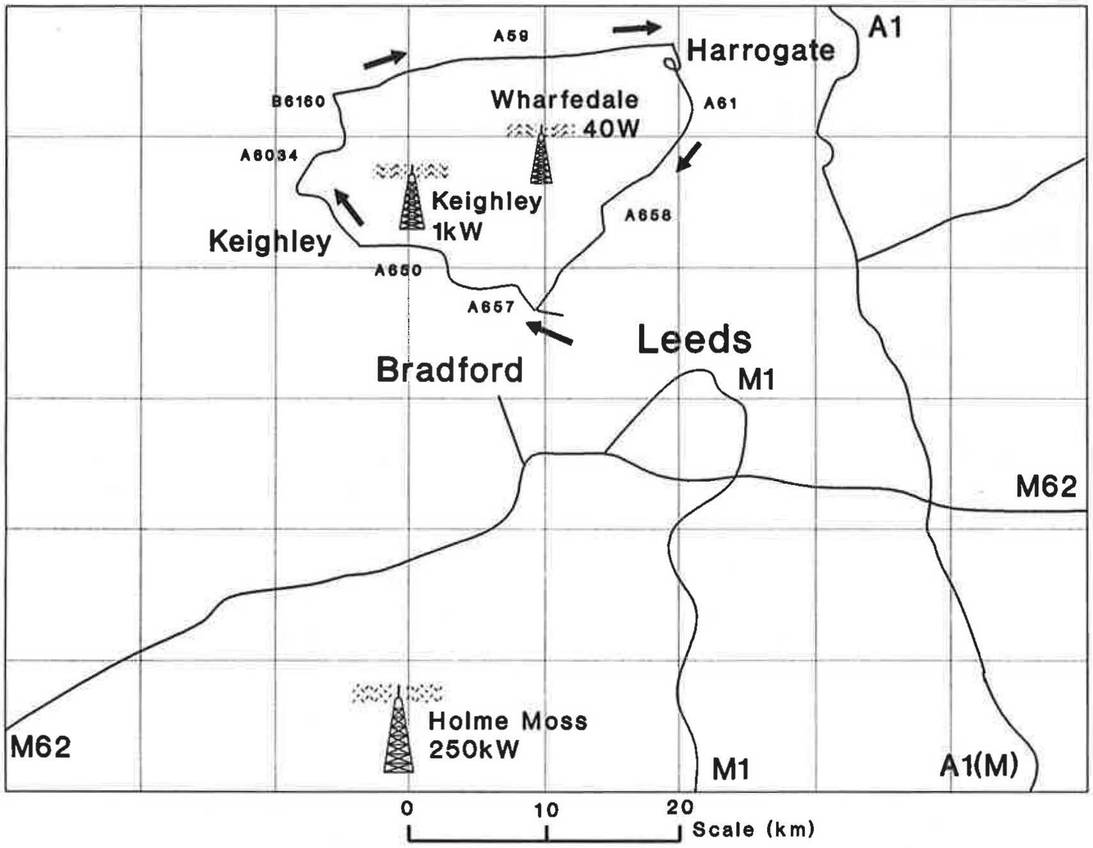

FIGURE 5 Map of RDS test circuit.

each country and throughout Europe. However, more detailed analysis is still required to investigate the rate at which signals reduce in strength over distance in order to develop optimal transmitter switching strategies for TMC receivers. Castle Rock Consultants has performed some analyses of these strategies but further work is still required to determine a near-optimal solution.

CONCLUSIONS

The TMC protocol has evolved through tests and evaluations in the RDS-ALERT project. Final modifications of the protocol will significantly increase its efficiency and flexibility, while maintaining a comprehensive structure capable of satisfying the requirements of a driver information system suitable for the 1990s and into the next millennium. RDS-TMC offers the exciting prospect of a practical application of information technology on the verge of implementation.

ACKNOWLEDGMENT

The RDS-ALERT project is being undertaken by a consortium of partners on a cooperative basis. The input of all partners to the project is duly acknowledged.

REFERENCES

1. European Broadcasting Union. *Specification of the Radio Data System (RDS) for VHF/FM Sound Broadcasting*. Doc. Tech. 3244-E, European Broadcasting Union, Brussels, Belgium, March 1984.
2. RDS-ALERT Consortium. *Review of Progress to Date on RDS-TMC*. DRIVE V1029, Deliverable 1, June 1989.
3. Castle Rock Consultants. *Radio Data System (RDS) Traffic Message Channel (TMC)*. Final Report to the Commission of the European Communities, Nottingham, England, Oct. 1988.
4. Commission of the European Communities. *The DRIVE Programme in 1989*. DRI 200, Brussels, Belgium, March 1989.
5. RDS-ALERT Consortium. *Report on Message Coding Field Tests*. DRIVE V1029, Deliverable 9, Jan. 1990.
6. RDS-ALERT Consortium. *Report on Message Reception Field Tests*. DRIVE V1029, Deliverable 11, Jan. 1990.
7. *Radio Transmitting Stations*. BBC Engineering Information, BBC Engineering Publications, London, England, 1989.

The views expressed in this paper are those of the authors and do not necessarily reflect the views of the consortium of partners in the RDS-ALERT project.

Publication of this paper sponsored by Committee on Communications.