The Case For High-Frequency ATIS

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In this paper a case is made for using a little-used part of the shortwave radio spectrum as a cost-effective means of broadcasting digital traveler information to rural and intercity users. Although the subject is technical, the material is provided in an easy-to-digest format. The target audience is state and federal transportation officials who believe that providing real-time traffic information is as much a part of transportation as building and maintaining highways. The approach uses low-cost off-the-shelf technology for both transmitting and receiving, and promises state-wide coverage for a total investment comparable to a simple highway advisory radio installation, about $10,000. The paper also describes how state departments of transportation or state police organizations can set up wide-area low-cost broadcasting facilities using a simple personal computer work station as an interface. The preliminary research needed and a strategy for follow-up operational tests are also described. The proposal describes the benefits and discusses the downside risks of developing this cost-effective medium for broadcasting traveler information.

This paper is written for state and federal transportation officials who believe that providing real-time rural traffic information is as much a part of transportation as building and maintaining our nation's highways and who are interested in broadcasting traveler information over wide areas at low cost.

BACKGROUND

What are the best radio frequencies for providing advanced traveler information in support of the intelligent vehicle-highway systems (IVHSs)? It is a question asked by many who plan for IVHS projects and as yet, there is no clear answer. This paper offers one possibility optimized for rural and intercity traffic using a bearer that currently has no commercial advocates and uses low-cost off-the-shelf technology.

Many frequency bands have been proposed for one-way and two-way advanced traveler information systems (ATIS) services. They include very low data-rate AM broadcast band subcarriers that have wide coverage, abandoned VHF-low frequencies below 50 MHz to FM and television broadcast subcarriers, the newly allocated 220 MHz channels through more conventional (though well-occupied) commercial bands, including piggybacked cellular and pager channels, and microwave beacons to direct satellite broadcasts to infrared roadside beacons with the capacity of gigabits per second.

The available bit rates on each of these, the coverage areas, the cost and complexity of providing receivers and transmitters, and the infrastructure support needed vary widely with each proposal. There are almost too many choices, yet no one frequency band is perfect for all uses and each choice represents some kind of trade-off in performance versus cost.

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Many proposals (though not all) suppose that the cost of establishing a broadcasting infrastructure (dedicated transmitters, broadcast towers, power feeds, data links to favorable sites, satellite uplinks, and the like) will limit general digital information broadcasts to modifications of existing services that can carry IVHS ATIS information on subcarriers or on a time-shared basis. Indeed, the cost of building and maintaining a new broadcast infrastructure—or even expanding it to new coverage areas—can be very high. The conventional wisdom of using what is already out there makes a lot of sense for a new service that must be supported, at least in part, by public agencies.

The problem is that these services still do not provide low-cost universal coverage. The difficulty is greater for rural areas of the country, where low population densities mean that there are few existing broadcast or paging facilities that can be adapted to provide ATIS services.

In this paper, one more possible ATIS bearer is proposed—one that uses dedicated channels at the extreme low end of the high-frequency bands (HF) or the upper ends of the medium-wave (MW) bands. The suggested system goes against conventional wisdom. Unlike proposals that try to maximize the use of existing commercial broadcasting infrastructure, HF ATIS requires establishing a new infrastructure with the hope of doing it at a very low cost.

Although referred to as HF in this paper to avoid confusion with the medium-wave AM broadcast band (.550 to 1.700 MHz), the proposed frequencies (2.00 to 2.10 MHz) are more properly a part of the MW bands. However, the service should work almost as well up to 3.50 MHz, passing the "official" 3.00 MHz dividing line between MW and HF (Figure 1).

THE VISION

The vision is simply a low-cost nationwide digital traveler information service targeted for rural and intercity travelers that is run as a partnership between the pubic and private sectors on a user-fee basis. The partnership would make the best use of a state's transportation and law enforcement agencies' ability to collect and store real-time traveler information and the private sector's ability to provide value-added services and market these services on a user-fee basis.

LOW COST AND RAPID IMPLEMENTATION

Much of the advantage of using the 2 MHz band is the low cost needed to set up an ATIS service—a fact that should particularly appeal to rural states that want to distribute traveler information over a wide area without investing a lot in labor and equipment. A complete low-power HF broadcast station should only incur an equipment cost of $5000. That is roughly comparable to the cost of

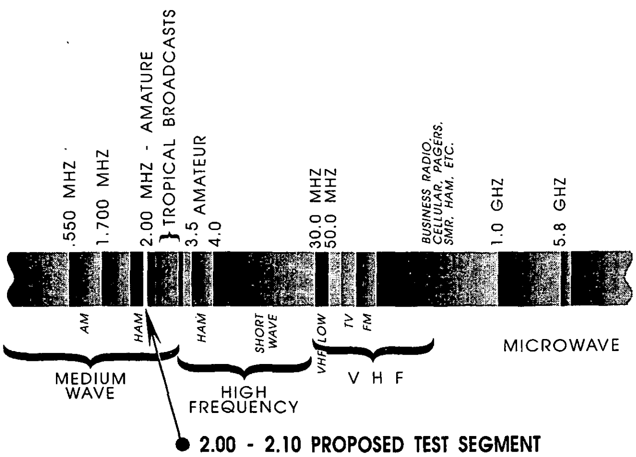

FIGURE 1 Simplified electro-magnetic spectrum.

a conventional highway advisory radio transmitter and would need no special installation site other than proximity to a state's traffic operations center or a link to a remote site.

Although there are currently no receivers being produced for use in vehicles for this kind of service, the cost to manufacture them should be very low. (There are receivers designed for receiving HF digital data in the maritime services and in the amateur services. The former are designed for high reliability in a hostile environment and the latter for low cost. Both are designed for use on many frequencies and many bands. For prototyping and operational tests either could readily be modified.) The circuitry needed to capture and demodulate the signals is only a little more complicated than a conventional AM transistor radio, which contains about $5 worth of parts. Even with the additional circuitry needed to provide digital detection and a standard RS-232 output port, the overall cost of the receiver in production could be as little as $50. It would fit into a package the size of a modestly sized internal or external computer modem. Indeed, the receiver would operate much like a modem, and for evaluation purposes a simple terminal program such as Procomm could be used to decode the messages if they were in a simple ASCII format. Receivers could be designed to provide audio tones compatible with existing computer modems or, for higher data rates and greater user simplicity, they could be combined into a single package that would provide decoded data over a standard RS-232 serial port. Figure 2 sketches some possible operational receiver configurations.

Despite the simplicity of broadcasting plain ASCII text, there is much to be gained by using standard message codes for traffic events and locations. Coded messages can be more readily sorted and stored for selected retrieval—a useful feature to prevent information overload for an expanded system. Much work is underway in this area. The protocols for coding digital traveler information are referred to as ITIS or ITIIS (International Traveler Information Interchange Standard). In North America, both ENTERPRISE (ITIS) and SAE (ITIIS) have technical working groups dedicated to developing an open standard for traffic messages, data storage formats, location coding, and dictionaries needed to support the coding of digital traveler information. Nothing would prevent dual broadcasting of both compact coded messages and plain ASCII text, each adapted to the sophistication level of the user's software.

Because of the low capital costs to be recovered by a completed system, the eventual user fees needed to support the service could be in the order of $10 a month if the service receives even a modest amount of support from its users. The receivers and the associated palm-top or desk-top computers needed to decode the messages could be built in as OEM equipment. However, such an architecture would also lend itself to third-party vendors or to add-on units to be added to rental car fleets in states such as Colorado, where rented cars are often used for intercity and recreational travel. The interface software that will be needed for desk-top or hand-held computers offers rich possibilities for the private sector to create and sell user-friendly programs.

Perhaps the best feature of such a system is that it could be easily and rapidly implemented, which would make it easy for any state or provincial transportation agency that can collect and process wide-area traveler information to provide ATIS services without large capital investments. The frequencies suggested, 2.000 to 2.100 MHz, are set aside for the federal government, which could authorize the state departments of transportation (DOTs) to operate the transmitters for them and set up the public-private partnerships needed to support the system on a user-fee basis.

WHY 2.0 MHz?

The suggested HF frequencies were found simply by listening for a few hours over the course of a year. It is educational for anyone to take a tour of the complete electromagnetic spectrum. If you have some time you can do that easily enough with one of the new high-tech broad-band general coverage receivers. But those of us who are not electrical or electronic engineering types can take a very quick tour with our imaginations.

Imagine the air around us being filled with low-energy photons that oscillate at frequencies from as low as 10 KHz, used to communicate to submarines around the world, through the frequencies of AM radio stations, through the suggested frequencies proposed in this paper, through world-wide shortwave frequencies, through short-range FM, television, and commercial business radio frequencies, through point-to-point microwave services' frequencies, and through the thousands of large "footprints" made by satellites in low-, medium-, and high-earth orbits. The cacophony of conversations that can be heard in a cocktail reception in a large hotel ballroom in a good-sized Washington, D.C. convention pales in comparison to what can be picked up by only a few feet of wire connected to a radio receiver, listening to the world talk to itself each day.

Listening to this raucous uproar, it is hard to believe that only 90 years ago it was all silent. Not a word nor conversation broke the silence that had lasted billions of years. Moreover, it has been a busy 90 years. The use of this limited resource has changed dramatically over the decades. Frequencies desperately needed in war were abandoned in peacetime, and receivers that could not fit into a large room now comfortably fit into the palm of the hand. Data has replaced much of the voice traffic. The spectrum from 2.0 to 3.5 MHz, which for decades reached out to so many maritime listeners, providing mobile services and tropical broadcasting, is now mostly unused in North America.

Where did all the users go? It seems that most have moved on to higher VHF channels for short-range communications or are relying on the global network of satellites for worldwide coverage. Although the international allocations have not changed in decades, there are now only a few dozen North American stations to be heard between 2.0 and 3.5 MHz in a typical evening of listening. The pro-

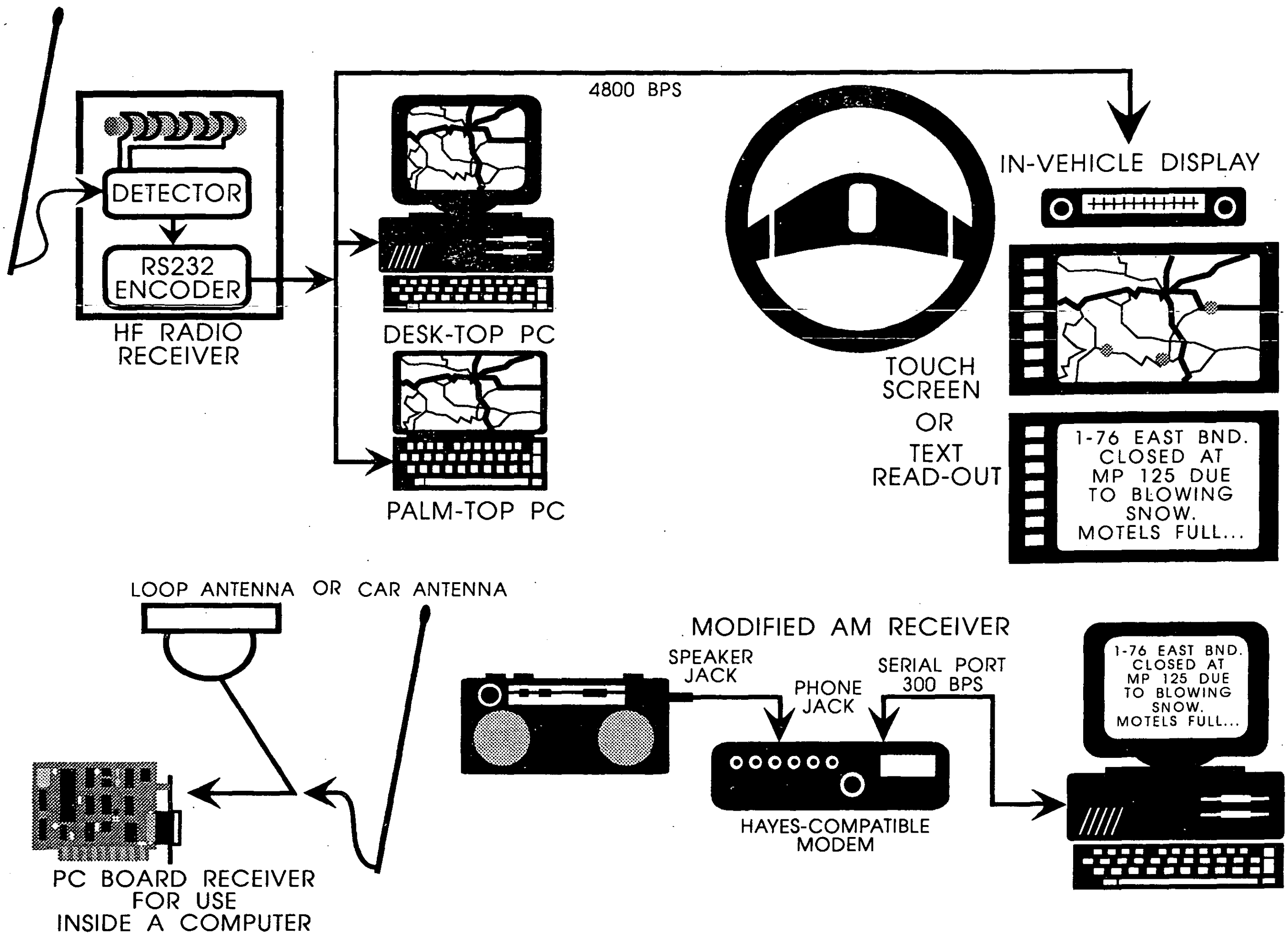

FIGURE 2 Possible receiver configurations.

posed test segment, from 2.00 to 2.10 MHz, is particularly quiet. This listener has regularly heard only three stations on the 20 or so available frequencies. The continuing abandonment of these frequencies by their former users means that there will little displacement, if any, of existing users. Even if the segment from 2.00 to 2.10 MHz is found to be unacceptable for administrative or technical reasons, there are a number of other potential segments between 2.0 and 3.5 MHz that could support a number of HF ITIS channels. Refer to the International Frequency Allocation Tables, which outline a number of segments that may be suitable.

The odd propagation characteristics, which are a disadvantage for other services using this part of the band, may be a plus for digital traveler information broadcasting of the type required by IVHS. Propagation in this frequency range is very different during the day and the night. During the day, ground wave and sky wave propagation is nearly ideal, with good coverage from 50 to 100 miles using a simple antenna. At night, the ground wave remains unchanged, but sky wave propagation is increased to carry signals much farther. The effect is familiar to anyone listening to commercial AM broadcast stations on what used to be called "clear channels." These signals can be heard 1000 miles or more away from the transmitter. Extreme nighttime coverage is undesirable, and the effect can be much reduced by configuring the transmitting antenna to direct the signals more or less vertically. This can be done with a basic dipole or end-fed wire antenna close to the ground. See Figures 3 and 4.

During the summer, the frequencies around 2 MHz are subject to static crashes from nearby thunderstorms. In the early days of digital communications using 5-bit teletype codes, this type of atmospheric noise and signal fading would cause "hits" that introduced errors into the copied text. Modern digital coding methods developed for maritime and other services using checksums, packets, and other forward error correction techniques have eliminated hits. Only correct text is received and interference simply reduces the overall data transfer rate.

Why not higher in frequency? Above about 3.5 MHz the HF spectrum is much better occupied and it is much more difficult to prevent signals from propagating far beyond their intended reception area. If the service is to expand nationwide, then higher frequencies must be avoided to prevent interference with stations in adjacent states. See Figure 5 for a representation of what typical low-power coverage areas might look like in the western United States.

Why not lower in frequency? This is certainly possible, but below 2.00 MHz there is much greater occupancy. The amateur 160-meter band from 1.8 to 2.0 MHz is well occupied in the winter months, and there are also other services in this segment. The segment from

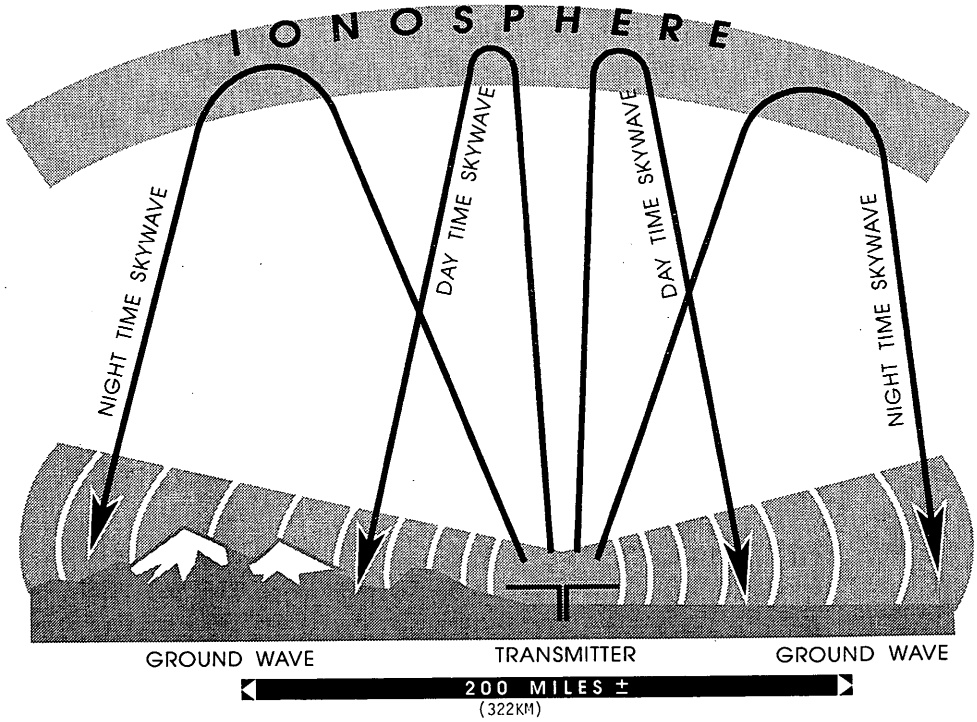

FIGURE 3 Skywave and groundwave propagation.

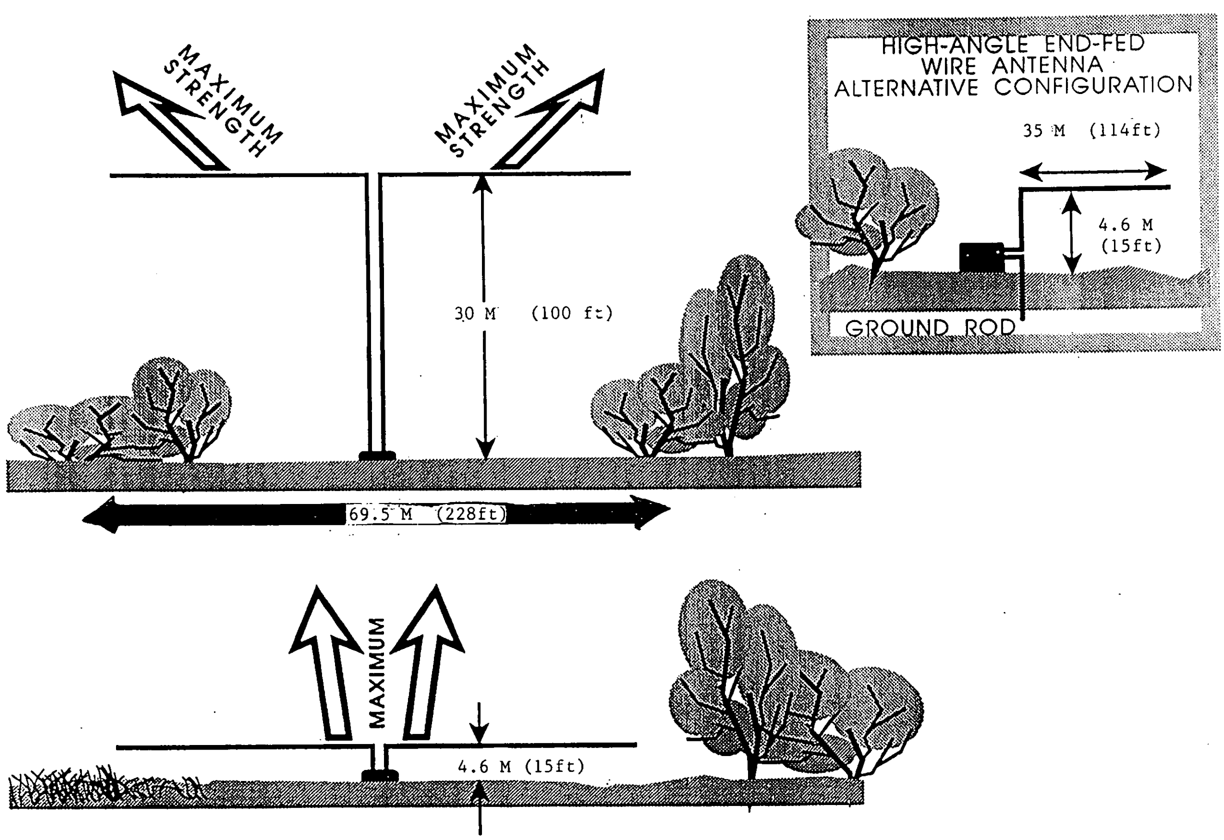

FIGURE 4 Radiation pattern versus antenna height.

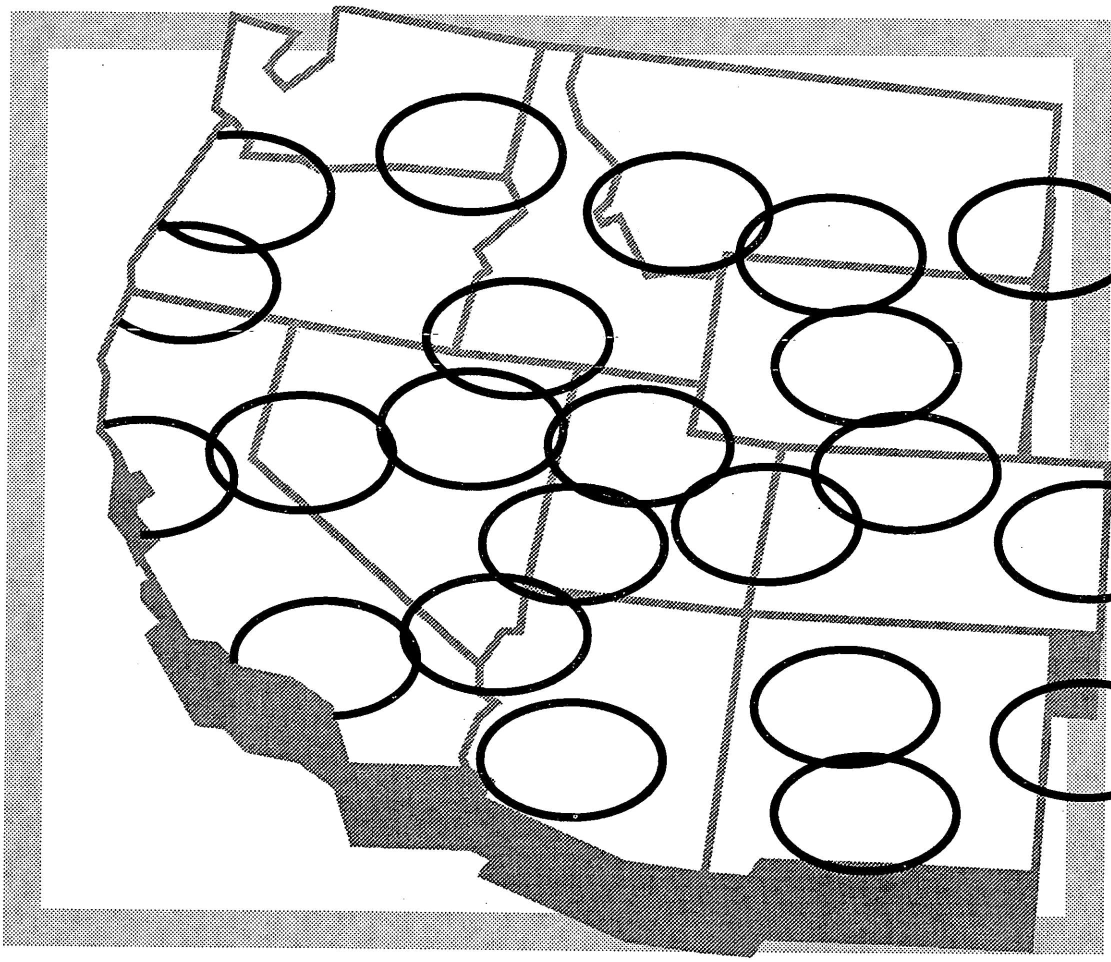

FIGURE 5 Possible western state coverage.

1.7 to 1.8 MHz could be used, but this segment is still being used by some wireless telephones, and the transmitting antennas are inefficient at these frequencies unless they are very long. Moreover, the powerful signals from adjacent AM broadcast stations mix and cause interference in some parts of the segment from 1.7 to 2.0 MHz.

Mountains (or even large foothills) create special problems for broadcasting travel information that long-wavelength carriers such as HF and AM radio address especially well. Unlike the line-of-sight propagation of VHF and FM transmissions, the ground waves from the lower HF and AM frequencies tend to wrap around large objects (such as mountains) and provide good coverage even in deep canyons and valleys where no FM coverage is available. At night, signals also arrive from an ionized part of the atmosphere that is more than 100 miles over our heads, allowing receivers to work anywhere except inside a metal building or a tunnel.

Why not in the AM band itself using subcarriers? AM subcarrier broadcasting may offer the best competition to dedicated digital frequencies at 2.0 MHz. The use of commercial AM broadcast stations from .550 to 1.700 MHz offers many of the same advantages, including wide-area coverage, as dedicated frequencies at 2.0 MHz, and it would certainly take advantage of the large number of available high-power AM stations that can be heard across the country. However, there are three apparent drawbacks: reduced bit rates, technical complexity, and tariffs.

It is uncertain what bit rates can be achieved with AM subcarriers in a field environment. Bit error rate testing scheduled for 1994 and 1995 should define the usable rate better, but expectations are that it will be very low—on the order of 100 bits per second or even less. (ENTERPRISE, a cooperative IVHS research, development, and implementation group among 11 state, provincial, and federal agencies, is planning field testing of AM subcarrier ATIS capabilities in 1994 and 1995.) With the overhead needed for error correction, throughputs may be as low as 25 bits per second. This compares to the 1200 to 4800 bits per second that may be available with a dedicated channel at 2.0 MHz. The low bit rates mean that compact codes must be used from the start with no possibility of transmitting plain ASCII text.

AM subcarriers are also technically complex. Unlike FM subcarrier encoders, which are simple to install and require no license, to install an AM subcarrier a technician must modify the station's carefully controlled master oscillator when it is off the air. RBDS FM subcarrier use is expanding in North America, and RBDS can be used for more than traveler information. One ENTERPRISE state, Minnesota, is currently testing ATIS broadcasting over an RBDS FM subcarrier in Minneapolis. Other organizations are planning to use FM subcarrier systems to distribute GPS differential correction codes. The Federal Communications Commission currently does not allow the modifications needed for an AM subcarrier, and special permits will be required for trials. The optimum encoding technique has still not been determined, but some of those that are being proposed would preclude the use of stereo systems that are now approved for AM stations. Fortunately, the technical complexity does not appear to raise the cost of the receiver significantly. The parts needed to modify a conventional AM receiver are not expensive.

Unfortunately, this is only true if used in production. For field trials and operational tests, test receivers are still large and expensive. Moreover, the investment needed to reduce AM subcarrier receivers to a single $20 integrated circuit is very large. This is not a problem if manufacturers decide there is a market for these receivers, but it can prevent low-level implementation if there is not. For FM subcarriers such as the North American RBDS and the European RDS standards, this investment has already been made and receivers are readily and inexpensively available.

Station owners need to make money to cover their operating expenses. Subcarrier capabilities, if used to any great extent, will be thought of as real estate to be rented out to users. Although these costs should be minimal to begin with, if competing uses develop for these capabilities, the costs may rise.

ADVANTAGES

Let us quickly summarize the advantages of a dedicated digital broadcast system at 2.0 MHz:

- Rapid implementation;
- Inexpensive transmission;
- Inexpensive reception;
- Use of readily available equipment;
- Easy prototyping for field trials;
- Easy management by modest state DOT or state police traffic management centers (Note: see Figure 6 for conceptual layouts of how a modest traffic information center could broadcast information on a variety of carriers using a single interface);
- Easy commercialization that may be a good introduction to public-private partnership for state DOTs;
- An open architecture that provides maximum potential for competition and service expansion;
- "Recycling" of old frequencies and no competition with the needs of existing services;
- Effective use of proven forward error correcting (SITOR/AMTOR) or packet digital technologies; and
- Useful information service during initial operational tests.

NEGATIVES

HF is sometimes dismissed as a potential IVHS ATIS carrier for various reasons. "It is unreliable, subject to fading and requires frequent frequency changes." Or HF "requires a number of frequency allocations to adapt to the rapidly changing propagation conditions. . . . network control and management [is] very difficult. . . . HF is also very susceptible to both atmospheric noise due to lightning and to artificial noise" (*1*). Because of the need for fairly large antennas when transmitting, HF is awkward to use for two-way mobile transmission. All of these statements are true for some HF systems, some of the time, for some communication needs, and if Texas had a need to broadcast traveler information to Brazil, it would find HF to be a very limiting media. However, none of these

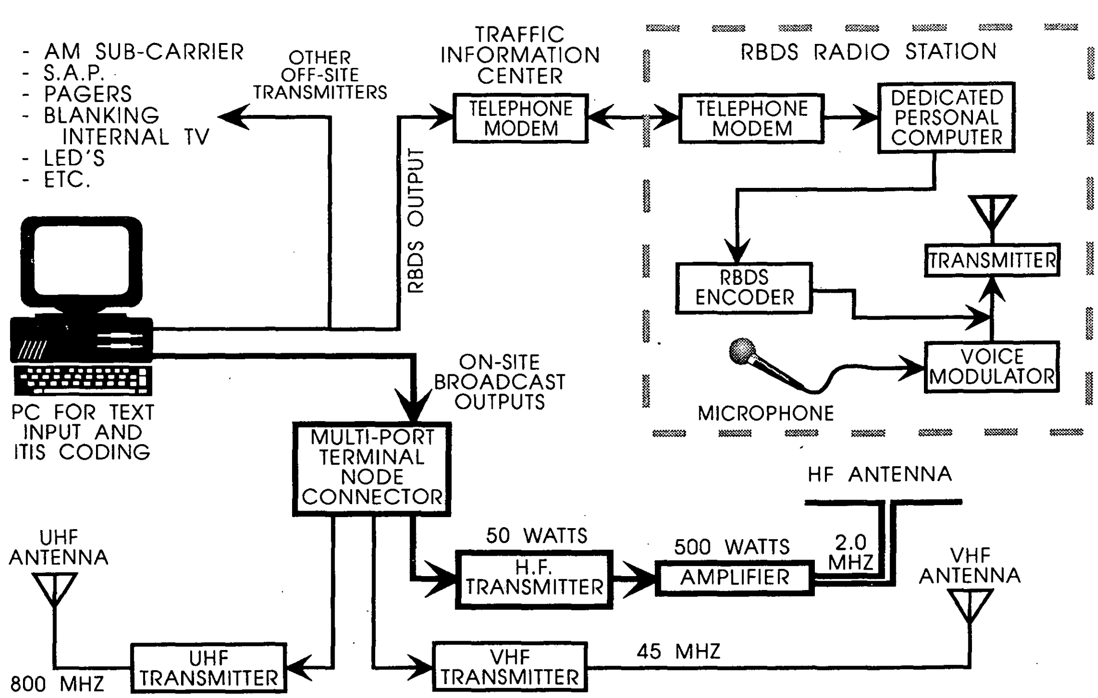

FIGURE 6 Conceptual traffic information center R.F. outputs.

concerns are valid for the types of short-range digital coverage described in this concept paper.

The remaining users in the lower part of the HF spectrum have shown that advances in digital radio broadcasting deal very well with these conditions. That is not to say that there are no unresolved issues: this writer is not aware of any situation in which a number of stations have occupied only a handful of frequencies. The potential for adjacent station interference is still largely unknown. HF antenna configurations are usually optimized for maximum propagation using a low angle of radiation. For ATIS broadcasting, where a shorter range and reduced interference is desired, antennas can be configured to radiate with a high angle of radiation. Not only would this reduce adjacent station interference, but because of the minimal support structures needed, antennas would also be much cheaper to install. Figure 4 shows two possible antenna configurations that provide a high-angle of radiation.

The other major unknowns are those listed in the proposed scopes of work: optimum antenna configuration, data rates, data formats, power levels, and the like.

FIRST STEPS

To reach implementation, the initial impetus must be provided by the federal and state DOTs. Public incubation is needed, because the private sector cannot be expected to front-end the investment needed for an open-architecture system that would provide no particular vendor any advantage over others. Beyond the early stages, transmitting facilities can be supported jointly by regional transportation agencies and the private-sector companies that operate in partnership with them. Conceivably, nonprofit corporations (set up independently, by state DOTs, or by university foundations) could assist in operating multistate systems.

Theories and concepts are just that. The first step to implementation must be proof of concept testing with trials in states with a variety of geographic features (mountains, plains, and Eastern U.S. intercity routes). If the trials do not work, the effort should be abandoned before performing follow-on operational tests, which would actually collect and disseminate useful information. Both concept testing and operational tests should be funded by the U.S. DOT and state and provincial transportation agencies as research and development projects.

WHAT'S NEEDED NOW

State IVHS researchers tend to think in terms of contracts, cooperative agreements, and scopes of work as means of getting programs started. To proceed further, a scope of work is needed to tell those who will potentially be providing the financial support what they would be getting for their investment. Here is a brief outline that is intended to be expanded into a full scope of work for the first two phases:

Phase I—Technical Proof of Concept

- Determine modulation methods and forward error correction methods to be tested;
- Determine hardware needs, location, and antenna configurations to be tested;
- Determine trial frequencies and obtain FCC test approval;
- Field test data rates and bit error rates, including the following:
  - –Coverage zones (day and night),
  - –Year-round testing,
  - –Radiation pattern testing,
  - –Interference testing from adjacent stations, and
  - –Power level requirements;
- Decide optimum configuration for operational tests;
- Make "go/no-go" recommendation for Phase II; and
- Complete detailed scope of work for Phase II.

Phase II—Full Operational Tests

- Make a full operational test description:
  - –Develop a standard architecture and data format;
  - –Use several hundred receivers;
  - –Create a prototype of encoding and decoding software;
  - –Distribute to a wide variety of users;
- Identify and develop potential private sector partners, including the following:
  - –Equipment manufacturers,
  - –Software developers, and
  - –Commercial traffic information providers;
- Complete overall system architecture;
- Establish initial institutional arrangements for a commercial service; and
- Begin informational presentations and outreach program to potential partners across North America.

INTERESTED?

Despite the potential benefits, HF ATIS cannot be implemented by a single state DOT. It must have the interest and support of many agencies responsible for traveler information and public safety. It must also have support from the private sector companies who are best able to find sponsors, set up private investment and manage user fees. Those who would want to support an HF ATIS service and would benefit from its establishment are scattered across North America. At least initially, the Colorado Department of Transportation's IVHS/New Technologies Group is willing to act as a focal point for those interested in this concept. No commitment is required. The Colorado DOT is just trying to put together a working list of those who are interested in the concept and would like to be kept informed about developments.

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REFERENCE

1. Weitzen, J. A., J. D. Larsen, and R. S. Mawrey. The Use of Meteor Scatter and Extended Range VHF for Vehicle Tracking and Communications. Presented at the Annual Meeting of IVHS America, Washington, D.C., 1993.

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