In spite of this apparent interest, few DTS/DEMS stations were ever constructed and, in 1984, the Commission staff began notifying licensees that their construction permits were forfeited. Nonetheless, interest persisted and, in the 1985 time frame, DEMS licenses were awarded to companies such as Via/Net Companies, BTV Digital Services, Southern New England Telephone Company, and Dama Telecommunications.

By 1992, there were approximately 20 remaining 10 GHz DEMS licenses in use and the Commission reallocated the 10.55 - 10.68 GHz band for point-to-point use, eliminating the 10 GHz DEMS service.[14] The 18 GHz DEMS allocation still exists.

C. DEMS/DTS Technical Specifications

A major contributor to the failure of the 10 GHz DEMS/DTS service was high equipment costs caused by tight technical specifications. The Commission itself eventually agreed that "DEMS has been slow to develop partially because of the cost of DTS equipment."[15] This service had a difficult time competing with local digital services offered by local exchange carriers. But the tight technical rules were due, in part, to the Commission's policy goal of having many DEMS licensees competing with one another -- a goal that was based upon too narrow a view of the relevant market. That is, the critical issue was the ability of the licensees to compete with the local telephone company rather than with one another. This is an important lesson that is directly applicable to the proposed rules for operation in the 37.0 - 40.0 GHz band.

The remaining subsections under this heading discuss some of the specific technical requirements that imposed cost penalties on DEMS/DTS and that may also impose unnecessary costs in the new band.

D. Modulation Efficiency and Frequency Reuse

The Commission imposed a 1 bit per second per hertz spectral efficiency standard on the DTS technology. This specification was originally applied to point-to-point microwave links and, for the reasons discussed earlier, a minimum standard of technical efficiency is reasonable where spectrum is shared among unaffiliated users. Moreover, the use of bits per second per hertz was not an unreasonable way of specifying spectral efficiency of point-to-point links that have the same bandwidth. But it was the wrong way to measure spectral efficiency in DTS for at least two reasons. *First*, as pointed out in Section III, it ignores the effects of frequency reuse and, through

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[14] In the Matter of Redevelopment of Spectrum to Encourage Innovation in the Use of New Telecommunications Technologies, 8 FCC Rcd 6495, 6509 (1993).

[15] In the Matter of Amendment of Sections 21.106(a)(3) and 94.71(c)(3) of the Commission's Rules and Regulations Relating to DTS Equipment, 2 FCC Rcd 3164 (1987).

frequency reuse, a designer can achieve a much more intensive use of the radio spectrum resource than what is reflected in a simple bits per second per hertz specification. *Second*, it is inappropriate for a band that may be subchannelized because it ignores the licensee's need to deal with interference from one subchannel to another within the system.

Despite the fact that the DEMS/DTS service was the first fixed service that the Commission created that specifically allowed frequency reuse, and despite the fact that frequency reuse is a powerful tool for achieving spectral efficiency, the agency declined to give any efficiency credits to DTS network designs that called for the reuse of the DEMS spectrum in a given area. Subchannelization is an essential element of frequency reuse because, by creating subchannels, a licensee may, for example, use sectorized antennas at a nodal station to isolate one sector from another to allow that same subchannel to be reused in several sectors. However, a 1 bit per second per hertz standard is more difficult to achieve in narrower bandwidths than in wider bandwidths, partly because of the additional filtering needed to meet the Commission's emission mask requirements. This additional filtering translates directly into higher equipment costs which, in turn, discourages the more efficient use of the radio spectrum resource through frequency reuse. Moreover, another form of frequency reuse can be achieved by means of CDMA whereby multiple transmitters share the same frequency through greater signal robustness but at the expense of some reduction in modulation efficiency as measured in bits per second per hertz. As pointed out earlier, this can lead to a significant increase in true spectral efficiency by allowing, for example, the same spectrum to be reused in immediately adjacent coverage areas within a large urban area. It is instructive to note that this spread spectrum approach has never been employed in point-to-point terrestrial communications links where the 1 bit per second per hertz requirement exists while it has been used in satellite communications where there is no such requirement.

Thus the experience with DEMS/DTS demonstrates through a "real world" example that a spectral efficiency standard in the form of a 1 bit per second per hertz requirement can discourage more intensive use of the scarce spectrum resource, impose higher equipment costs than would otherwise be necessary, and preclude the use of potentially more spectrally efficient technology. This lesson from the 10 GHz DEMS/DTS experience is fully applicable to the 37.0 - 40.0 GHz microwave band and demonstrates that the concerns raised in Section III are, indeed, valid.

E. Emission Mask and Subchannels

The purpose of an emission mask is to minimize interference from a system operated by one licensee into a system operated by another licensee on an adjacent channel. To our knowledge it was never intended for a service where a licensee employs subchannels and uses network design principles (e.g., lower power, polarization isolation, or antenna directivity) to minimize interference from one subchannel into another.

Nonetheless, for 10 GHz DEMS/DTS, the Commission imposed a tight emission mask that was difficult to achieve and that imposed equipment cost penalties. The tight emission mask was more difficult to implement for FSK modulation than for PSK modulation. The Commission eventually agreed and, in 1987, it modified the emission mask. In doing so, it found that the modification would decrease equipment costs and would allow some equipment (e.g., equipment using PSK modulation) to achieve greater path lengths.[16]

This situation arose in part because the emission mask that was initially adopted was based upon one assumed subchannel bandwidth but systems were developed that employed a different subchannel bandwidth. It also arose because the emission mask was applied to the subchannel radios as part of the equipment authorization process. The DEMS licensee was therefore denied the ability to use radios with less stringent emission masks, even though the licensee might have another, less expensive, means available to control interference from one subchannel to another. It could be argued that, in the 37.0 - 40.0 GHz band, the emission mask specified in Section 21.106 of the Commission's Rules may be needed to minimize interference at the channel edge (i.e., interference between systems operated by different operators). But it is clearly not needed to control intrasystem interference between a single licensee's subchannels.

Moreover, even near the channel edge, the emission mask need not apply to individual radios. Subchannel radios located near to the channel edge could be allowed to operate at lower power levels as a way of avoiding interference into systems operated by other licensees on adjacent channels. This would be consistent with the Commission's proposal for aggregating adjacent channels contained in footnote 189 of the Notice. To permit this, the emission mask compliance for individual radios should be eliminated and the equipment type acceptance process modified accordingly.

F. Antenna Sidelobes

In the DEMS/DTS proceeding, the Commission initially adopted a requirement for antennas with a gain of 38 dBi for 10 GHz internodal links. In 1985, a manufacturer pointed out the requirement for a gain of 38 dBi at this frequency would require a 3.25 foot diameter dish, and requested a rule change to permit antennas with a gain of 34 dBi -- a requirement that could be met with a 2.0 foot dish. The Commission adopted this technical change in 1988 on the basis that smaller, lower cost antennas could be used.[17] The Commission never adopted specifications for DEMS/DTS nodal station antennas because it was recognized that wide beam antennas were appropriate for point-to-multipoint transmissions.

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[16] 2 FCC Rcd at 3164.

[17] In the Matter of Amending Sections 21.108(c) and 94.75(b) of the Commission's Rules, 3 FCC Rcd 7335, 7336 (1988).

In the 37.0 - 40.0 GHz proceeding, the Commission has proposed to require Category A antennas. While this requirement may be readily achievable in this band for point-to-point links, it precludes point-to-multipoint operations from a single antenna. Since the licensee is permitted to subchannelize and reuse its frequencies, it may choose to install radios in a hub and spoke arrangement to achieve a configuration that is equivalent to a wide beam model. However, it is likely that this configuration is more expensive than using a wide beam antenna. As in the case of 10 GHz DEMS/DTS the proposed antenna beamwidth requirement could increase costs without any discernable public benefit.

G. Number of Channels and Channel Bandwidth

At 10 GHz, the Commission placed a very high value on "multiple entry."[18] It established a service with as many as 13 DEMS licensees per city at 10 GHz and, later, allocated another ten channel pairs at 18 GHz. Because the total amount of spectrum was relatively limited, each 10 GHz licensee received only a 2.5 MHz channel pair or a 5 MHz channel pair. This was at a time when 11 GHz point-to-point microwave channels were 40 MHz wide. Because of the small amount of bandwidth per channel, it was difficult to design a system that carried adequate traffic and was cost competitive with telephone company digital transmission services. During the 1980s, when DEMS should have been a developing service, commercial data communications requirements were increasing from T-1 (1.54 Mbps) levels, which could have been carried on DEMS/DTS subchannels, to Ethernet (10 Mbps) levels, which could not be carried. Today, 10 Mbps Ethernet cards are widely available for personal computers at prices below $50, and Fast Ethernet (100 Mbps) cards sell for $200-300. In a few years, consumer electronics products (e.g. digital TVs and digital VCRs) will employ the IEEE 1394 communications link, at speeds around 200 Mbps.

The 50 MHz channel pairs proposed for 37 GHz are based in part on the limited amount of spectrum available and the presumption that there should be competition between 37 GHz licensees. But as commercial data communications requirements grow larger, a 50 MHz channel may not be adequate and the proposed spectrum cap of 700 MHz may be too constraining, especially considering the fact that the market for local digital communications is dominated by the fiber-based telephone companies and, to a much lesser extent, Competitive Access Providers ("CAPS") rather than other microwave licensees.

V. Potential Sharing of the Spectrum with Federal Government Users

In prior sections of this report, we have shown that, if the Commission establishes a system of quasi-property rights in the spectrum in the 37.0 - 40.0 GHz band, it can rely upon economic forces to ensure that the spectrum is used efficiently. More specifically, we concluded

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[18] 86 FCC 2d at 386.

that, except for the need to establish technical rules to protect other radio systems/services, there is no need for the Commission to establish minimum standards of spectral efficiency or requirements for frequency tolerance, emission masks, adjacent channel interference, or antenna characteristics in the 37.0 - 40.0 GHz band. In the Notice (para. 13), the Commission asks for comments on whether point-to-multipoint operations should also be allowed in the 37 GHz band and whether there is a requirement for mobile operations in the 37 GHz band. Mixing point-to-point, point-to-multipoint, and mobile operations is normally fraught with difficulties if the operations are separately licensed and the spectrum is shared among different licensees. For example, compared to a single point-to-point link, a single point-to-multipoint microwave system will typically require more unused spectrum-space around it to prevent intersystem interference. Similarly, providing seamless roaming of mobile units becomes impossible if the needed spectrum in certain areas is already assigned to another licensee.[19]

However, the Commission apparently recognizes that point-to-multipoint and mobile modes of operation are largely incompatible with the point-to-point mode if separately licensed. Thus, instead of proposing to separately license such operations, it is proposing to include them within the uses permitted under the proposed licenses.[20] It follows from our earlier analysis that, under a system of quasi-property rights, the licensee is in the best position to judge whether the public would be better served by point-to-point, point-to-multipoint, and mobile modes of operation or some combination of the three. Furthermore, because the licensee would be in a position to control the resulting intra-system interference, he or she could "mix and match," depending upon market needs in particular geographic regions within the licensed service area.

The clear advantages of relying upon property-like rights and economic forces to determine the best mix of point-to-point, point-to-multipoint, and mobile operations would be almost totally undercut if the Federal government is allowed to share the spectrum on a first-come, first-served basis within a licensed service area. Not only would wide-spread sharing preclude certain types of operations, it would lead to inefficient use of the spectrum and the need to develop minimum requirements for frequency tolerance, emission masks, adjacent channel interference, and antenna characteristics, since the interference would no longer be solely intrasystem within a licensed service area. It would have other undesirable consequences as well:

First, it would significantly increase the risks that potential bidders face in bidding for the proposed licenses. This would surely reduce the revenues received from the auctions because potential bidders would face tremendous uncertainties in trying to foresee how many Federal government systems might be added in the future. Taking into account the need to provide

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[19] The interference situation between the 1.9 GHz band PCS systems and the incumbent fixed microwave systems demonstrates the difficulties that such sharing produces.

[20] Our analysis applies equally to area-wide licenses, including MTA licenses.

interference protection to a very limited number of existing operations (i.e., the nine authorized Federal government fixed links at two installations described in footnote 5 of the Notice), is one thing, but coping with an unknown number of future operations at unknown locations is something entirely different.

Second, as described in Section IV, the Commission's experience with the failed DEMS/DTS service demonstrates how fragile competition in local telecommunications services can be. The uncertainties associated with an unspecified amount of future Federal government sharing within the licensed service area would reduce the attractiveness of the 37.0 - 40.0 GHz band and significantly diminish its potential role as an important new source of competition to the incumbent local exchange carriers.

Third, while licensees can be expected to keep certain basic information to meet their internal interference coordination requirements, the added costs of producing and maintaining secure, computer accessible databases would further burden the nascent competitors. Perhaps more importantly, it would force the new entrants using the band to provide sensitive marketplace information to existing and future competitors.

Rather than undermining the advantages of relying upon property-like rights in the 37.0 - 40.0 GHz band, the Commission could, in consultation with the National Telecommunications and Information Administration ("NTIA") and other affected agencies, seek ways of meeting Federal government communications needs that are more consistent with an economics approach. In fact, it can be argued that the band should not be shared with the Federal government at all, since the government can acquire needed services offered on non-government systems (whether in the designated bands or elsewhere) just as it commonly does in other areas. Indeed the cause of spectral efficiency may be well served by such an approach. This is because, as explained earlier, the winners of the auctions in the 37.0 - 40.0 GHz band will have strong incentives to use their spectrum efficiently while Federal government users, under present conditions at least, will have considerably less incentive because they are insulated from competitive, marketplace forces.

If Federal government agencies have legitimate, specialized communications needs that cannot be readily met by commercial service providers, there may still be other ways of accommodating those needs short of undermining the quasi-property right approach. For example, the Commission could adopt rules that allow a service area licensee to "sub-lease" spectrum to government agencies on a contractual basis to meet those specialized needs. Such an approach would eliminate most, if not all, of the disadvantages associated with issuing separate frequency authorizations to government agencies within the licensed service areas.

VI. Summary and Conclusions

Based upon the analysis contained herein, we conclude that, other than for the need to establish technical rules to protect other radio systems/services, there is no need for the

Commission to establish minimum standards of spectral efficiency or requirements for frequency tolerance, emission masks, adjacent channel interference, or antenna characteristics in the 37.0 - 40.0 GHz band. We further conclude that specifying such standards and requirements could seriously distort technology choices and raise costs unnecessarily. We also conclude that fifteen years ago the Commission established a new radio service but handicapped it with stringent technical rules that substantially raised equipment costs. The service failed. But the lessons remain, and we conclude that those lessons should be given substantial weight in adopting technical rules for the 37.0 - 40.0 GHz band. Finally, we conclude that the clear advantages of relying upon property-like rights and economic incentives to regulate the use of the 37.0 - 40.0 GHz band would be almost totally undercut if the Federal government is allowed to share the spectrum on a first-come, first-served basis and we suggest other means for meeting legitimate Federal government requirements that are more consistent with this Nation's traditional reliance upon such rights and incentives.