ISART 2003

The Electrospace Model

as a Tool for

Spectrum Management

Robert J. Matheson
NTIA/ITS.M
matheson@its.bldrdoc.gov

Spectrum Management

Spectrum management functions
- Who gets to use spectrum?
- For what functions?
- Under what restrictions?

Multiple spectrum management paradigms
- Command and control
- Market based/property rights ←
- Non-licensed spectrum commons

Does not necessarily reflect present or future policies of NTIA

Radio System Basics - 1

Radio systems have:

- Transmitter (including transmitting ant)
- Propagation path
- Receiver (including receiving antenna)

Communications – move data from transmitter to receiver location.

Sensing – Compare received signal with transmitted signal to study path (radars, etc.)

Radio System Basics - 2

The Electrospace describes radio signals: transmitter and propagation.

Electrospace describes a signal's potential to provide service and to cause interference to other users.

The receiver is completely independent from the electrospace. (No receiver electrospace).

Interference -1

Interference – any distortion of the received desired signal caused by extraneous, unwanted radio signals. (excludes multipath, internal noise)

No sharp line between acceptable and unwanted interference. All interference is unwanted, even if it only uses up some of FEC budget.

An "externalized cost," which must be regulated.

Interference - 2

Interference occurs only in receivers.

Interference is *always* caused by an inadequate receiver and could be fixed by "good-enough" receiver (though "good-enough" might be very complex and expensive).

"Interference protection" means "cheap receiver."

Receivers

A receiver that is not "good-enough" causes interference only to receiver user.

Receivers cause no externalized costs to other users, thus no need to regulate receivers. Receiver user is only party with proper motivation to select receiver.

User Groups, consumer groups, etc., have legitimate need to set receiver performance.

The Electrospace

Electrospace (described by Hinchman in1969) is a 7-variable description of EM field strength (hyperspace).

•Physical location – lat., long., height	3-dim
•Frequency – MHz	1-dim
•Time - µS, hours, or years	1-dim
•Direction-of-arrival – azimuth, elevation	2-dim

A good-enough receiver can separate signals having non-identical electrospace descriptions.

Electrospace Rules

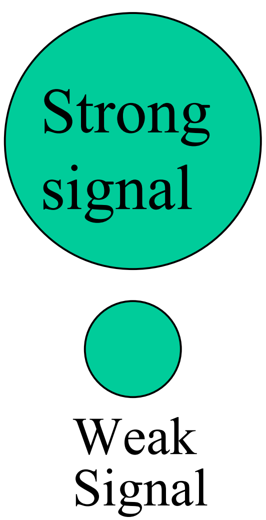
A transmitter must be licensed to operate within an electrospace region (all 7 dimensions),

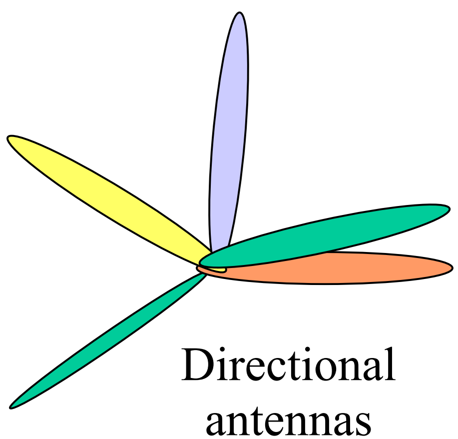
Field strength above X μV/m is a signal. All signals must be entirely within licensed electrospace boundaries.

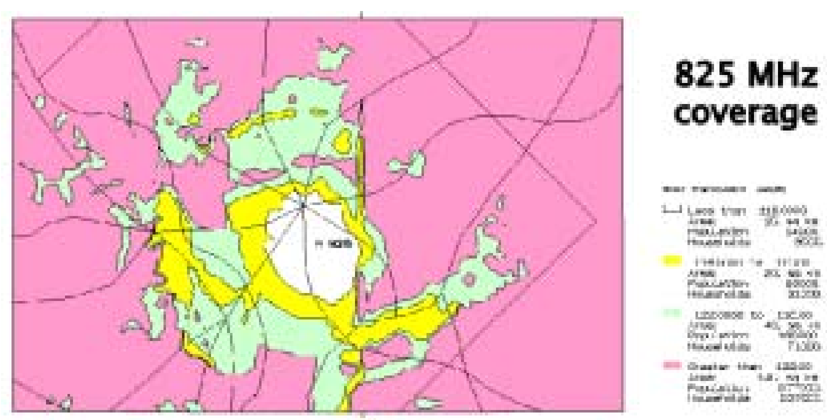
Licenses can be aggregated or divided, without limit; flexible secondary markets.

Spatial Dimensions

Any spatial region: microcell to BTA, modify with directional antennas. Caution: some areas cannot be used well; coverage affected by terrain and buildings, height above ground. Match spatial to coverage.







Frequency Dimension

Frequency dimension is well behaved and intuitive.

Frequency can be divided into narrower channels or added together for wideband systems

Time Dimension

FCC recently mentioned "time" as one additional dimension that they would divide.

- Months – seasonal uses
- Hours – to broadcast special football
- Hours – midnight-to-5am daily to send low cost computer updates.
- 10 ms TDMA timeslots every 50 ms.

Angle-of-Arrival - 1

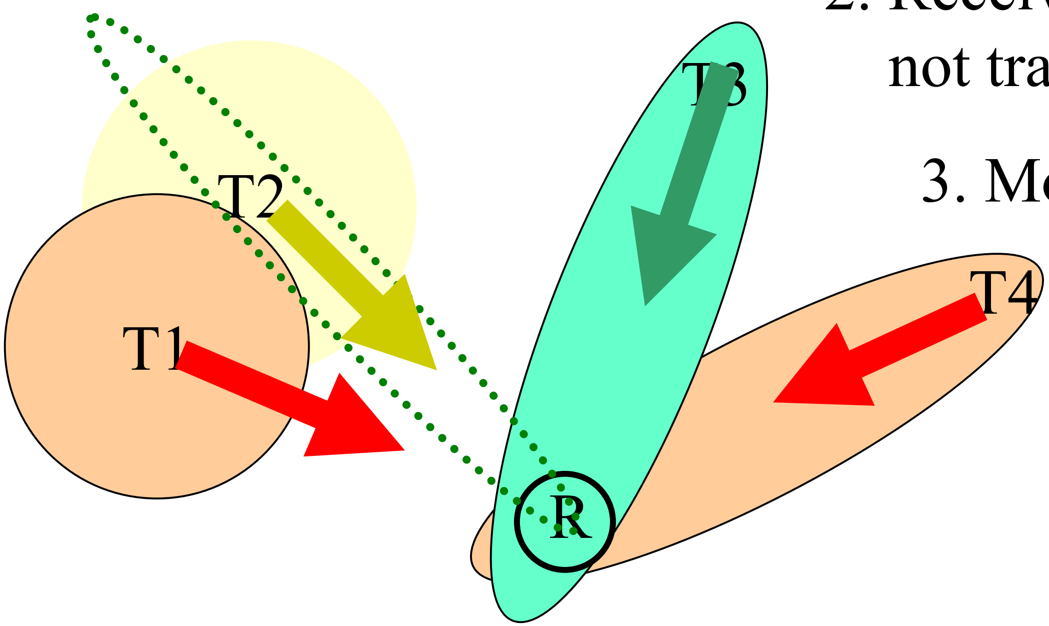
Consider multiple signals at same frequency, arriving at same location, but from different directions. (typical point-point microwave site)

Separate with directional receiving antennas.

Separate with finer resolution using narrower receiving antenna beamwidths. (Note that this has nothing to do with transmitting antenna BW)

Angle-of-Arrival -2

1. Angle-of-arrival is different from coverage area.
2. Receiver beamwidth counts, not transmitter beamwidth.
3. More transmitters, narrower receiver beamwidth.



Angle-of-Arrival - 3

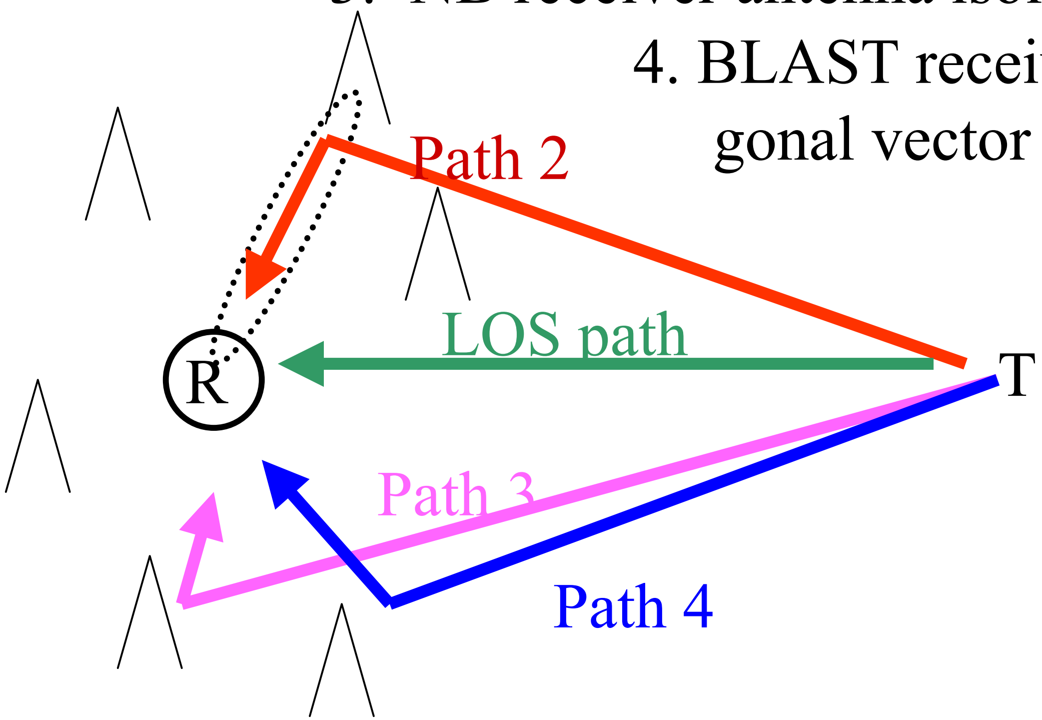
Traditional angle-of-arrival is limited because only usable angle is free-space direction.

Much more useful if could broadcast multiple beams from single transmitter that appeared to come from different directions.

BLAST technology exploits a generalized angle-of-arrival technique to make multiple independent channels between xmtr and rcvr.

Angle-of-Arrival - 4

1. Narrowbeam line-of-sight path (pt-pt microwave).
2. Multiple NB paths scattered from landscape.
3. NB receiver antenna isolates each path (difficult).
4. BLAST receiver forms multiple orthogonal vector sums to mathematically generate paths (easier).



5. Future application of generalized angle-of-arrival, using less-expensive techniques

Pure Electrospace Rules:

Field strength above X μV/m is a signal. All signals must be within licensed electrospace.

Any dimension can be aggregated or divided, without limit; flexible secondary markets.

No restrictions on uses, power, modulation, sites, etc. Only: stay within E-S boundaries.

Problems with Pure E-S Rules

E-S rules assume "ideal" receivers: no affect from signals outside of receiver bandwidth.

Real receivers are not ideal. Receiver front end overload, IM products, leaky bandpass filters.

High unwanted signal levels require other users to buy more costly receivers. This externalized cost should be controlled, i.e. require regulation.

Can Pure E-S be Fixed?

- Frequency management systems must not leave externalized costs (interference).
- Are there modifications to pure E-S that will mitigate externalized receiver costs?
- Modifications must still permit flexible-use and aggregation/division.
- Modifications must clearly define limits, so that legal responsibilities are known.

E-S Rules: Frequency Management

Initial receiver strategy: Control maximum amplitude and minimum frequency separation of unwanted signals (these create need for better receivers).

- Follow duplexed band designs (freq. separation)
- Limit maximum field strength near transmitters at ground level, where receivers are located. (Probable cause of 800-MHz band problems.)
- Limit transmitter power per MHz.
- Will prevent interference in most cases (co-site, etc)

ES Rules - Transactions

Aggregation/division rules strategy:

Make no neighbor worse off after a transaction.
("worse off" means "requiring better receiver")

- Scale max power proportional to total bandwidth.
- Control power distribution within aggregated bandwidth, so extra power is not at edges, causing adjacent-channel receiver problem.
- Limits on total transmitter field strength (FS) near receivers (ground level near base station)

Receiver-wise ES Rules:

- Observe E-S signal boundaries (X dBμV).
- Observe band architectures, power limits
- Various limits optimize for various services
- Flexible services and system configuration
- Flexible rule-based aggregation/division
- Minimum regulatory intervention needed.

Electrospace Rules Today?

- Pure Electrospace rules work only for systems using ideal receivers (note 800-MHz interference)
- Receiver-based ES rules needed to form basis for practical market-based, flexible-use bands
- ES bands based on exclusive ownership of rights--which can be aggregated, divided, etc.
- Need to find best numerical limits for each band/service. Gain some practical experience.

ES vs Command & Control

C&C manager (Government) optimizes individual bands for specific systems and (existing) technologies.

C&C formulas guarantee level of service and service area, using proven technologies.

C&C provides optimized performance, stable environment, and minimal opportunity for significant innovation or change.

ES vs Spectrum Commons

- Commons has provided broad flexibility for many low-power non-licensed systems.
- Interference protection today via low power and control of local configurations.
- High power may cause massive interference
- Smart, agile systems can evade interference if there is unused spectrum somewhere.
- Cost of interference avoidance vs alternatives

End of Paper

Questions?

Copies of paper were too late to include in the conference proceedings, but are available now.

Does not necessarily reflect present or future policies of NTIA