DECISIONS

ON OUR WAY TO

SPACE COMMUNICATIONS

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Outline of talk

Introduction -- Worldwide communications without satellites
Developments during World War II: rockets and microwaves
TIROS, the first weather satellite – April 1, 1960
Space communications by reflection
RELAY, an active communications satellite
Orbits for communications satellites: low altitude or geostationary
INTELSAT satellites
Courses which I developed and taught
References

Worldwide communications without satellites

1945-1954: I was in the U.S.; my parents were in Brazil

- I wrote them a letter every week

Letters by ship often took a month or more

- Took even more time when delayed by WWII censors

Telegrams would took days; even short ones were expensive

I chose to work on satellites, to benefit underdeveloped countries

- After elementary particles for 2 years, and biological warfare for 2 years

Early Progress that made Artificial Satellites possible

Werner von Braun :

V2-rockets, 3600 mph, to bomb London

Britain and U.S.:

radar (microwaves), to detect bombers & subs

Bell Laboratories:

transistor, digital circuits, computers.

First Satellites in Space

Competition between Russia and U.S.

Sputnik 1, October 4, 1957

First Russian satellite with radio transmitter

Explorer 1, January 31, 1958

First U.S. satellite with radio transmitter

Project SCORE, RCA, December 18, 1958

Signal Communications by Orbiting Relay Equipment

First communications satellite. Message by Pres. Eisenhower:

“America’s wish for peace on earth and goodwill toward men everywhere”

Alternatives for Space Communications

Reflection from the MOON's surface
- Large surface, but 220,000 (?) miles away

Reflection from a 100-ft aluminized Mylar sphere, named ECHO
- Seen from earth as a moving bright star. Launched August 12, 1960

Reflection from thousands of small, metal needles – HAYSTACK
- Length of needles optimized for a specific frequency

Active satellite: needs receiver, amplifier, and transmitter
- Requires antennas, amplifiers, solar array, battery, etc. TELSTAR, July 10, 1962

RELAY satellite, built by RCA

- TELSTAR 1, built and launched earlier by AT&T, July 10, 1962
  - First active, direct-relay communications satellite
  - Spherical shell keeps solar input constant
- RELAY 1, launched December 13, 1962
  - Two traveling wave tube amplifiers (TWTA)
    - Generated a noisy click whenever tested in a vacuum
    - Each turned on and off with a solid state switch
  - Solar array maximizes the area inside the rocket cone
  - Active thermal control; temperature controlled internal louvers

Final satellite tests: Vibration & Thermal Vacuum

Thermal Vac: solar simulation or thermal gradient

Vibration tests well developed for military weapons and airplanes

During launch, rocket motors generate much vibration

Thermal vacuum tests were new

The sun's heat can be simulated with a carbon arc ("solar simulation")

or, with the temperature of a nearby surface ("thermal gradient")

The NASA project manager insisted on a solar simulation test,

but in the end admitted the thermal gradient test was better for RELAY.

Orbits for Communications Satellites

Low earth orbit (LEO) or geostationary (GEO)

LEO: Circular, a few hundred km above earth

- orbit around earth in 1.5 hours, velocity of 7.7 km/sec
- Communication through an individual satellite limited to half an hour
- Examples: TELSTAR, RELAY, IRIDIUM, GLOBALSTAR

GEO: Circular, equatorial, 35,786 km above earth's surface

- In 1945, Arthur Clark suggested GEO, with an orbit period of about 24 hr
- Much larger orbit (x 5.6) than earth' radius = 6,378 km
- Delta velocity required: 7.7 +2.4 + 1.5 km/sec = 11.6 km/s total
- Geostationary over one point on equator (but needs stationkeeping)
- Usage of individual satellite is continuous
- Examples: Syncom 3, Intelsat 1 (Early Bird)

Communications Satellite Corp. (COMSAT)

- Created by Congress to build a global communications system
  - Starting launching GEO satellites; quicker to get a global system
- Intelsat I (Early Bird), launched over Atlantic Ocean
  - Provided continuous communications between North America & Europe
- Intelsat II (three satellites), over Atlantic, Eurasia, and Pacific
  - A global communications system (as predicted by Arthur Clarke)
- Intelsat III (eight satellites), launched sequentially, as needed
  - Bearing problem resulted in poorer performance and shorter lifetime
  - Provided communications until Intelsat IV satellites were launched

INTELSAT IV Satellites

More capability required larger satellites

- Only expansion room inside the rocket shroud was along the axis
- Required spinning around a minimum moment of inertia
- Fuel tanks were in spinning part

After operation in orbit, a problem developed

- Two (of four) fuel tanks, on opposite sides were unbalanced
- Yet they should be, since there was a pipe connecting them
- Maybe hydrazine was frozen – but all temperatures were normal
- Why were the fuel tanks unbalanced?

INTELSAT IV problem of unbalanced tanks

The problem: one tank had more fuel than connecting opposite tank

Solved by Hughes (built sat) + Control Center + Comsat Labs

Expert at Hughes suggested cause: nitrogen bubble in connecting line

Generated slowly when hydrazine (fuel) decomposed

Comsat Control Center (SCC) analyzed telemetry (measured wobble)

George Huson, at Labs, studied problem with glass tubing and water

Gary Gordon, at Labs, analyzed dynamics with computer simulation

Control Center suggested firing a specific thruster, to purge bubble

At first no change. GDG's analysis predicted the fuel would balance after 15 min.

After expected time period, the wobble disappeared

Problem did re-occur, when another bubble formed after many months

COURSES which I developed and taught

Satellite Thermal Design

Satellite Orbits (low orbits and geostationary orbit)

Satellite Reliability (Intelsat IV)

Spacecraft Technology

FORTRAN – a computer programming language

SPEAKEASY – language similar to MatLab and MathCad

Link Budgets (power losses and power gains)