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CONTROLS OF INTERACTION DYNAMICS OF ORBITAL ASSEMBLY

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Building structures and spacecraft in orbit will require technologies for positioning, docking/berthing, and joining orbital structures. A fundamental problem underlying the operation of docking and berthing is that of controlling the contact dynamics of mechanical structures actuated by active mechanisms such as robotic devices. Control systems must be designed to control these active mechanisms so that both the free space motions and contact motions are stable and satisfy specifications on position accuracy and bounds on contact forces. For the large orbital structures of the future, the problem of interactive dynamics and control is fundamentally different in several ways than it was for spacecraft docking in the past. First, future space structures must be treated as flexible structures—the operations of docking, berthing and assembly will need to respect the vibrations of the structures. Second, the assembly of these structures will require multiple-point contact, rather than the essentially single-point positioning of conventional spacecraft docking. Third, some assembly operations require the subassemblies to be brought and held in contact so that successful joining can be accomplished.

A preliminary study of contact stability and compliance control design has resulted in the development of an analytical method and a design method to analyze stability. The analytical method analyzes the problem of stability when an actively-controlled structure contacts a passive structure. This method makes it possible to accurately estimate the stiffness of the passive structures with which the contact motion will become unstable.

The analytical results suggest that passivity is neither achievable in practice, nor necessary as a design concept. A contact control system need only be passive up to a certain frequency; beyond that frequency the system can be stabilized with sufficiently small gains. With this concept the Center has developed a design methodology for achieving desired compliant contact motions. This design method is based on H-infinity norm optimization, which makes it possible to consider both driving point mechanical impedance and systems robustness to modeling uncertainty. A laboratory facility has been set up to verify experimentally the analytical and design theory.

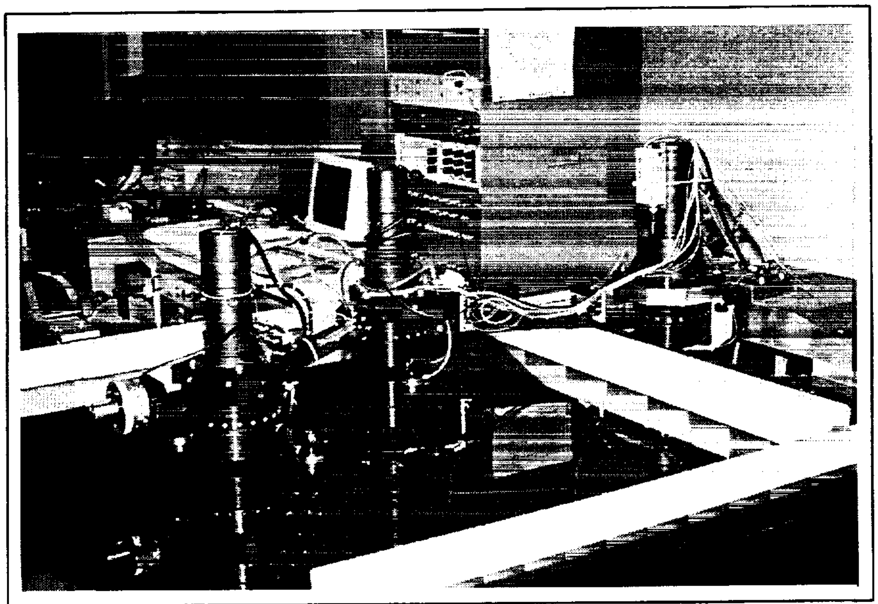


Fig 3.1 Planar robot manipulator testbed for interaction dynamics and control

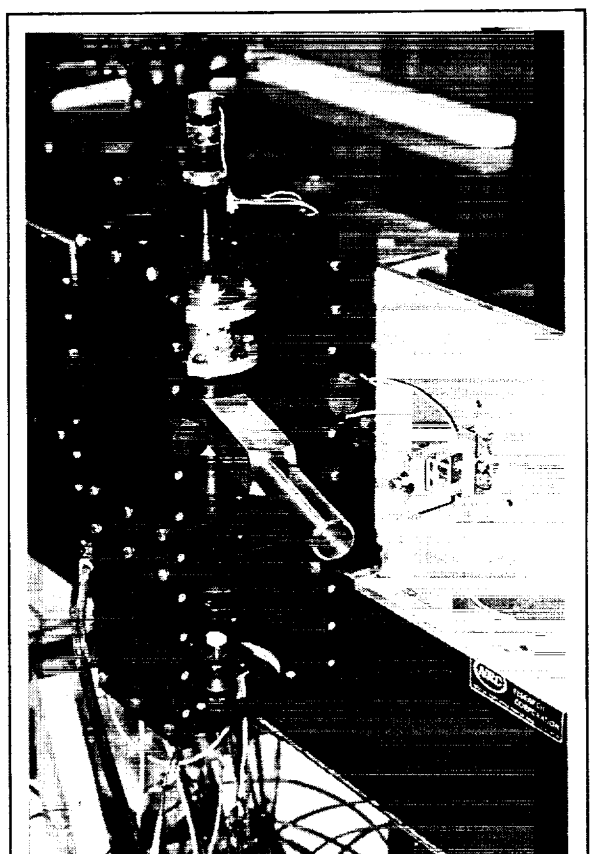
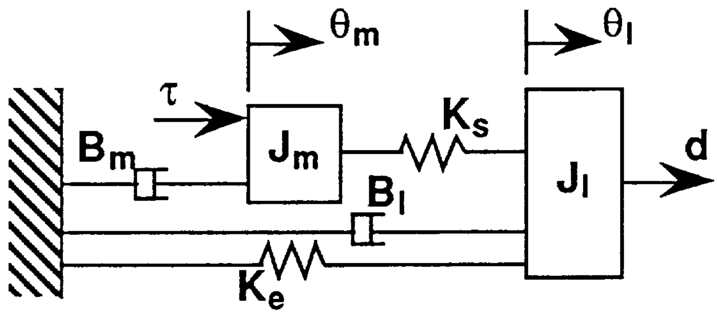


Fig 3.2 Single degree-of-freedom manipulator for interaction dynamics and control



Parameter	Value	Units
Motor Inertia, J_m (reflected to output side)	0.0934	kg-m^2
Motor Viscous Damping, B_m (reflected to output side)	3.4	N-m/(rad/s)
Harmonic Drive Stiffness, K_s	1600	N-m/rad
Load Viscous Damping, B_l	0.7	N-m/(rad/s)
Representative Load Inertia, J_l	0.64	kg-m^2
Gear Ratio	100:1	N/A

Fig 3.3 Model and parameters of the testbed in Fig. 3.2

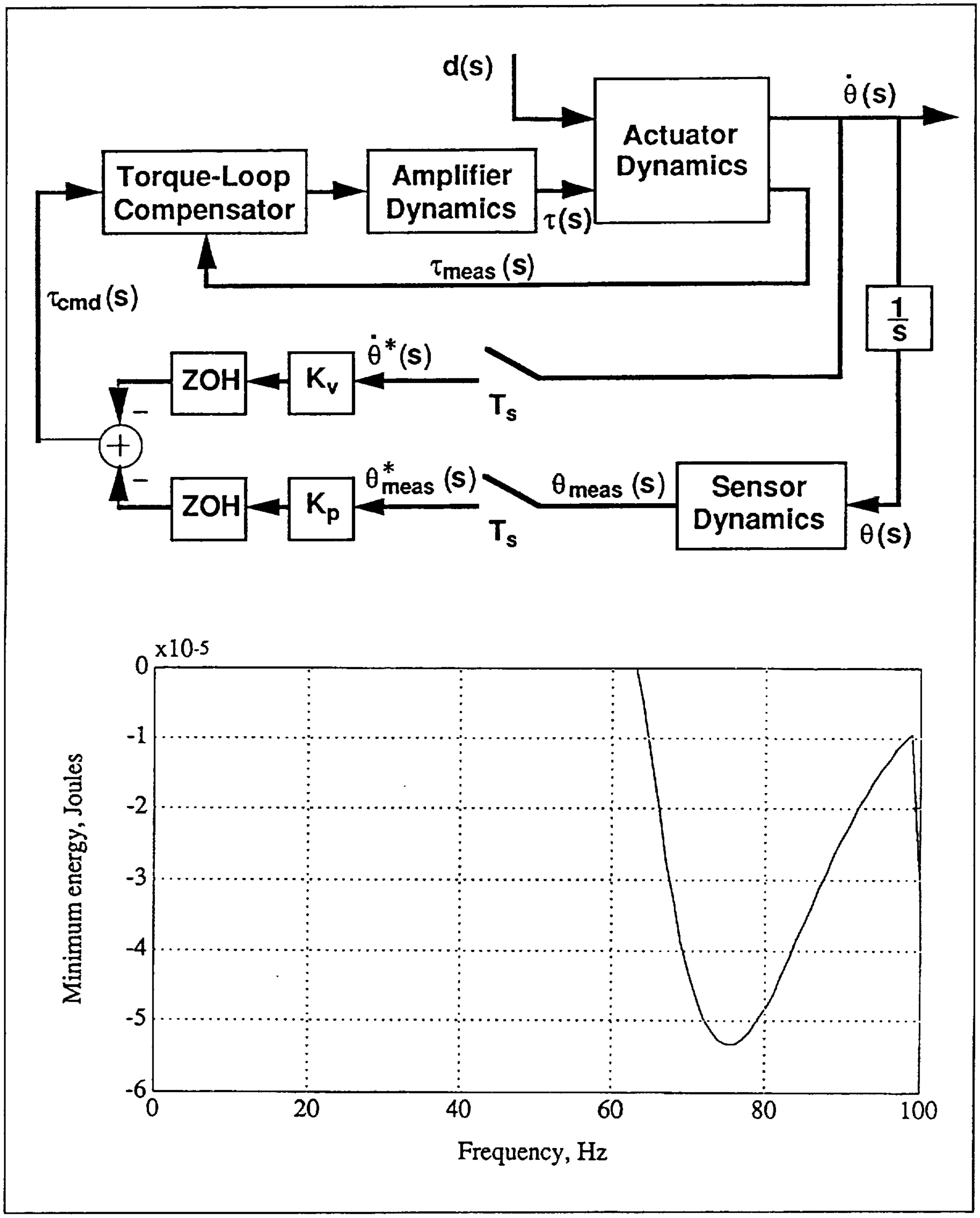


Fig 3.4 Model of the testbed with PD controller and passivity analysis

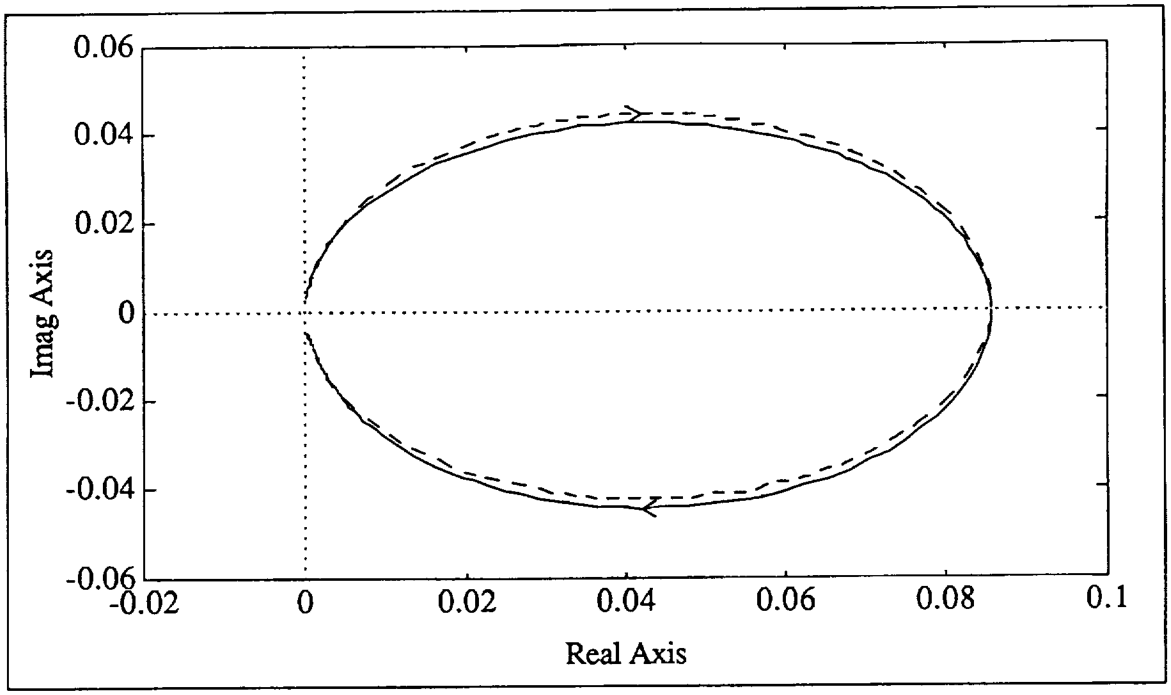


Fig 3.5 Nyquist diagram of the admittance

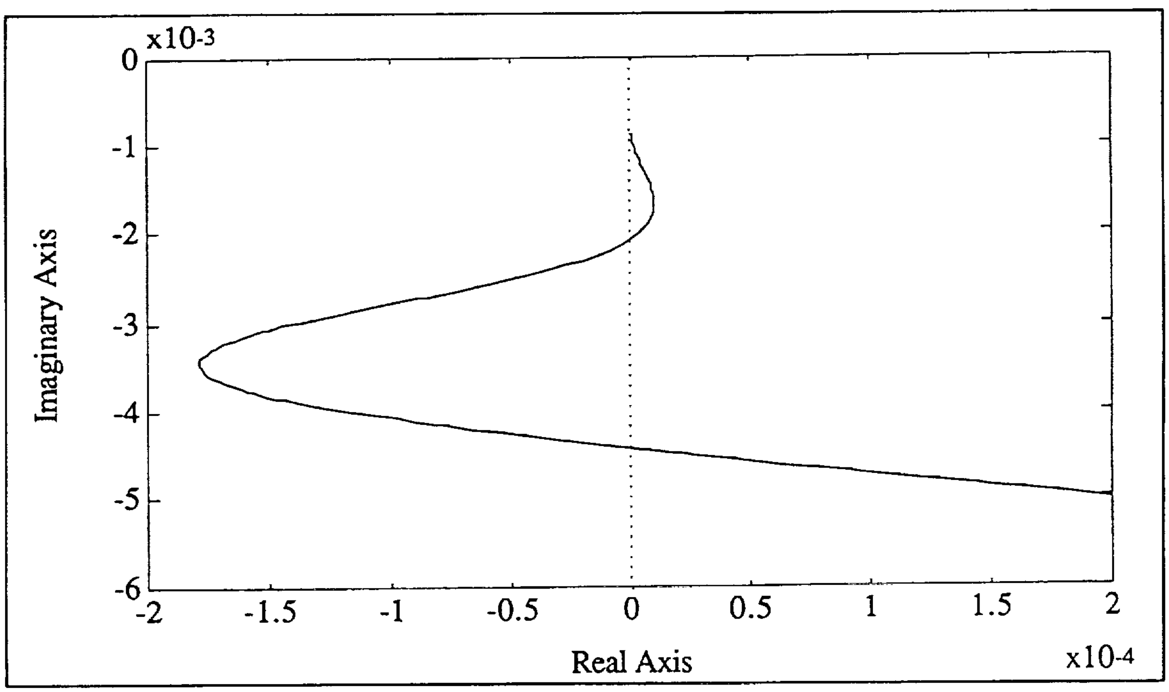


Fig 3.6 Nyquist diagram of the admittance above 50 Hz

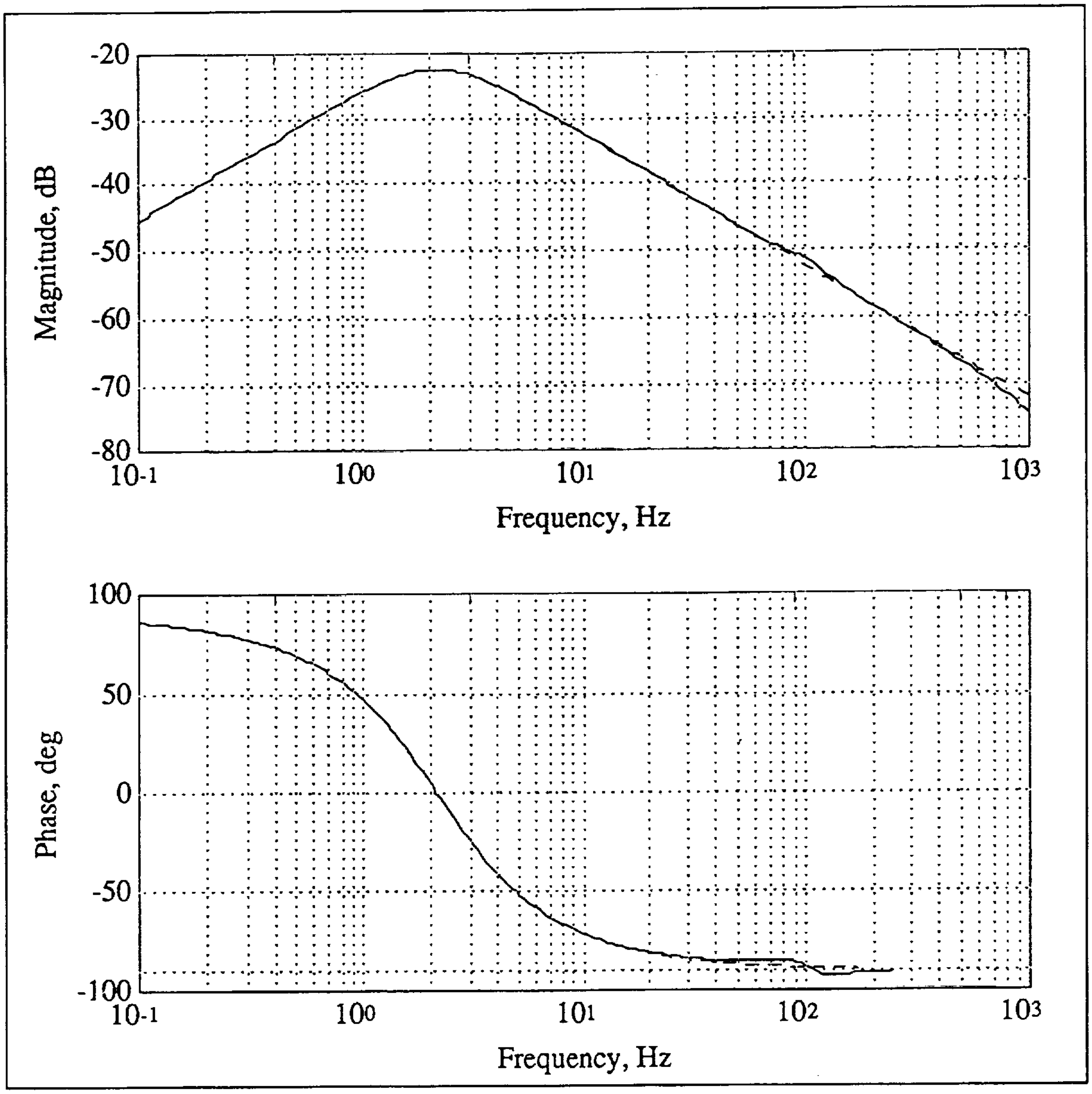


Fig 3.7 Achieved (solid line) and target (dashed line) admittance responses using H_∞ design method